SEASONAL, TIDAL AND DIURNAL MOVEMENTS AND BREEDING OF THE FREE-SWIMMING CRUSTACEA MALACOSTRACA OF PORT ERIN BAY

THE INSHORE FEEDING OF THE COAL-FISH (GADUS VIRENS) AND OTHER OFFSHORE FISH IN PORT ERIN BAY

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Introduction

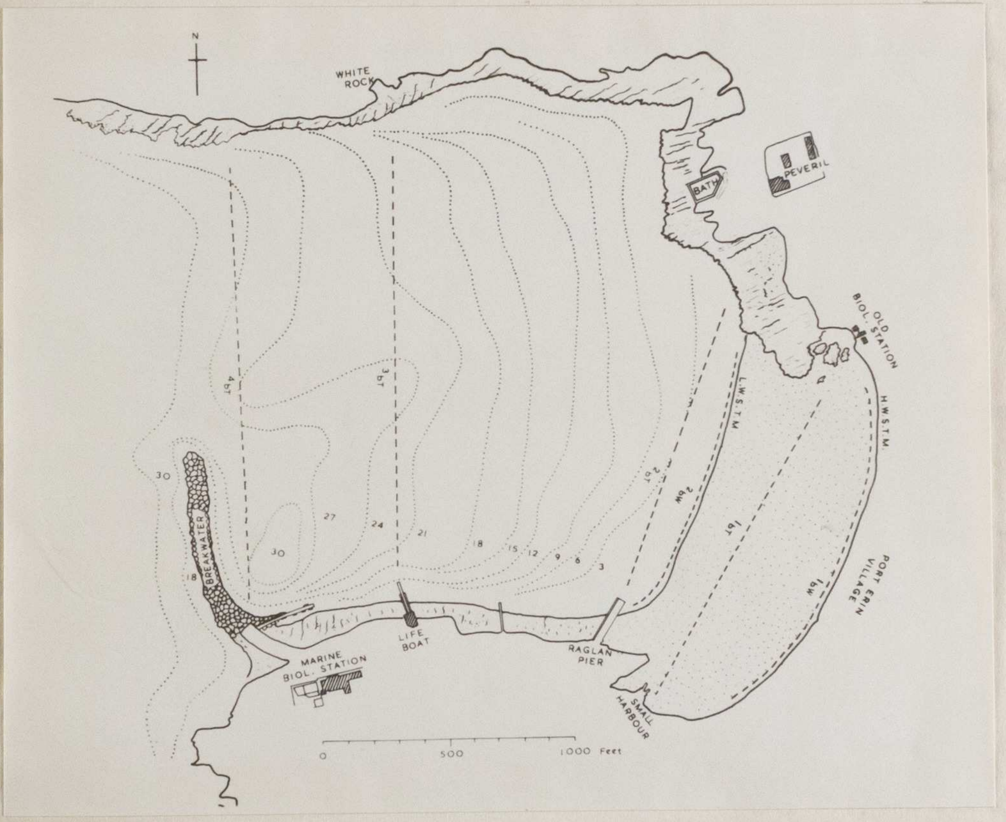
The present investigation includes a study in Port Erin Bay of:
(1) the ecology of the free-swimming Crustacea Malacostraca,
(2) the feeding habits of some inshore feeding fish and the correlation of feeding habit with the distribution of the food species.
The survey regarding Crustacea Malacostraca covers their general distribution, seasonal abundance, seasonal and diurnal movements, and reproduction.

The inshore feeding fish were mostly obtained by seine-netting on the beach after dark. The stomach contents of the fish were examined, qualitatively and quantitatively, and compared with the fauna.

Port Erin Bay (Chart 1) lies near the south west end of the Isle of Man and is almost rectangular in outline, with north, east and south sides 700 metres long. The bay is open to the west and is sheltered on the north by the cliffs and hills of Bradda, which is about 350 ft. in height (Pirrie, Bruce and Moore, 1932), on the east by the village of Port Erin, and on the south by the hill of the slopes of Cregneash. The beach on the eastern shore is a wide stretch of fine clean sand inclining slightly toward the south west. Toward high water mark on the beach there is a definite increase of gravel and pebbles, especially toward the north end "where denudation has almost entirely removed the finer materials, leaving an area of coarse gravel with pebbles" (Pirrie, Bruce and Moore, 1932). Along the east side there is also a considerable extent of reefs, intersected by areas of boulder beach.

The water between low water mark of the beach and the breakwater deepens gradually to 9 m. and is here termed the shallow water region. The bottom in this area is mainly sandy and bare, but the strips along the south and the north sides, and inside the breakwater are scattered with large boulders which are richly vegetated.

The ruined breakwater extends northward nearly one-third of the way across the entrance of the Bay and affords a considerable measure



<u>Chart 1.</u> <u>Port Erin Bay.</u>

General topography showing localities included in the survey.

. . . . . . submarine contours (ft. at low water) based on Admiralty Chart 2094, revised 1930.

of shelter from the west. This is covered at mid-tide.

Tidal range From tidal observations made at Port Erin Bay in 1949 by the co-operation of staff and research workers at the Marine Biological Station, the mean neap range was found to be 8 ft., the mean spring range 15 ft., and the extreme spring range approximately 20 ft.

Temperature The temperature in Port Erin Bay was recorded by the non-scientific staffs. Daily readings were taken respectively at 0900 and 1600 hrs. The monthly means of 1949 to 1950 are plotted against the time as in Fig. 1. Additional records of the surface and bottom were taken once a month during May 1950 to April 1951 at stations along the water's edge, at the life-boat slip and inside the breakwater. Appendix 1. It will be seen that in the summer months the temperature is higher on the surface than at the bottom and close to the water's edge. Conversely, in the winter months, the surface temperature is either slightly lower than at bottom or shows no significant difference.

Salinity No accurate observations on salinity at Port Erin Bay are available. "From May 1934 to March 1939, samples from Port Erin Bay were also taken three times per week and titrated by Bruce. The salinities followed those for Chicken Rock very closely." (Proudman, 1940). Fig.2 shows the salinity at Chicken Rock in monthly values from January 1935 to December 1946 as presented by Gilles (1949). It will be seen that the salinity generally reaches a maximum of 34.24% in April and decreases to a minimum of 34.03% in October.

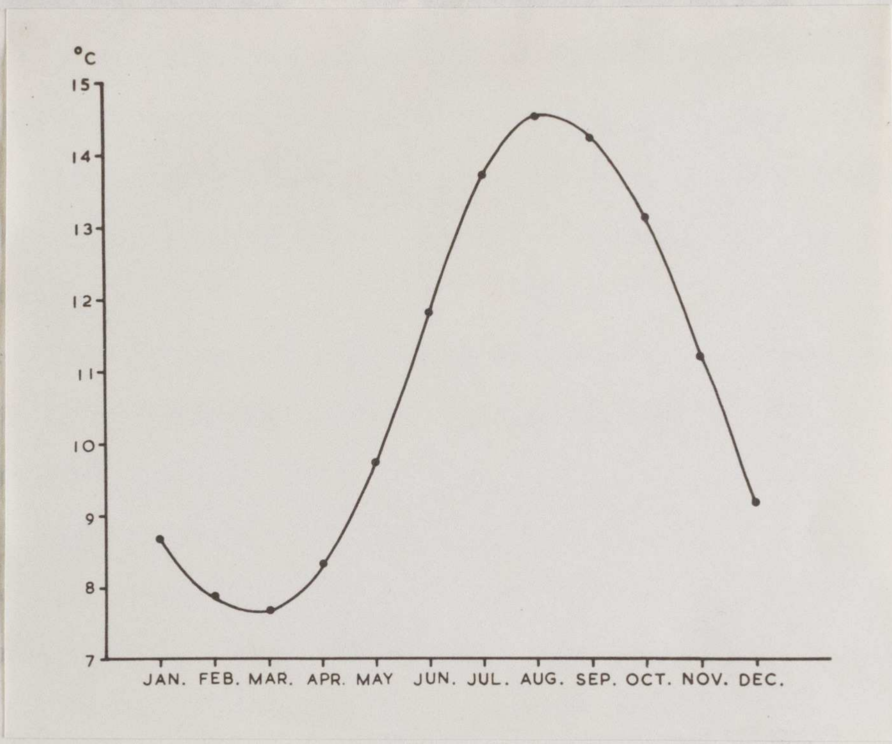


Fig. 1. Mean monthly temperature (°C) of sea at Port Erin Bay during 1949 - 50

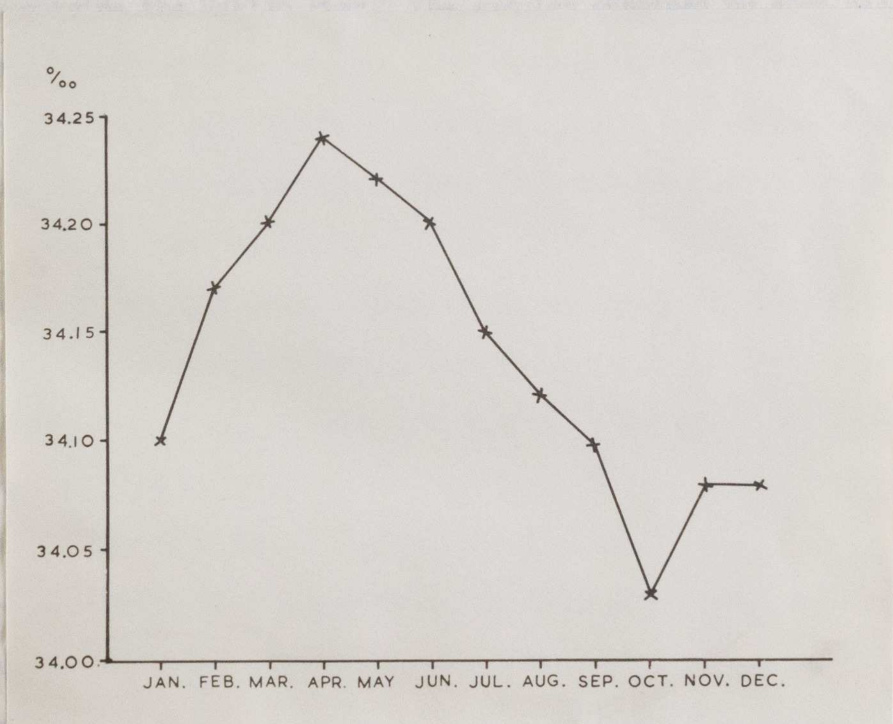


Fig. 2. Mean monthly salinity (‰) at Chicken Rock during 1935 - 46 (Gilles , 1946)

Methods and Material. The observations were carried out during the period from May 1949 to August 1950, on the Biological Station motor boat "Runa", in Port Erin Bay, and by wading along the water's edge both at high and low tides. The area covered in the present work extended from the high water mark to the breakwater, with a surface area of approximately 800 x 600 metres.

Four lines of sampling were chosen at low water, and five at high water, to cover the distribution of the fauna in the Bay. These stations were chosen as follows:

(1) Low water edge (2bw) (Chart 1), including all states of low water from neaps to springs. Samples were taken by wading from the north to the south end of the Bay, a distance of about 360 m., at a depth that covered the rim of the net, each haul lasting about 11 min.

(2) Raglan Pier towards the Peveril Hotel (2bt), a distance of 450 m. at low water and 500 m. at high water, each haul lasting from 13 to 17 min. On extremely low spring tides, the course of towing was slightly outside the Raglan Pier. The samples obtained on such occasions were marked with asterisk (*).

(3) Life Boat slip to White Rock (3b), a distance of 550 m. at low water and 660 m. at high water, each haul lasting from 17 to 20 min.

(4) Inside the breakwater, from the Biological Station (4b) to a conspicuous cleft under Bradda Head, about the same distance as 3b. At high water, one additional haul was made from inside the small harbour to the old Biological Station (1bt), a region about mid-tide level, with a distance of 430 m. and lasting about 12 min. A wading sample was also taken along the edge of high water, lasting about 13 min.

Once each month four samples were taken in 24 hours at both high and low waters.

The lines of samples were kept roughly constant with the aid of land marks in the daytime and by shore lights after dark. The light on Raglan Pier, the street lights behind the life-boat slip, and the lights in the Biological Station furnished the land marks on the south side of the Bay. The north side of the Bay was darker at night, save for the lights at the

Peveril Hotel and the White Rock opposite the life-boat slip, which could be identified from a distance. The course under such circumstances underwent a very slight deviation. There were other causes which tended to alter the course of sampling:

(i) strong east and west winds which sometimes rose suddenly, and

(ii) fishing gear such as the floating lines of crab pots and drifting nets shot by fishermen in the spring.

Attempts were made to achieve comparable results on the quantitative studies of the inshore fauna, both as regards the seasonal abundance and as regards the population of the surface and the bottom layers in relation to diurnal movement. It became apparent that a round-mouthed net, suitable on surface tows, was inadequate for sampling near the bottom where the population tends to be concentrated in a narrow layer on or just above the sea floor; for such hauls the D-net was used.

Another difficulty encountered in this present work was to design a gear suitable both for the shallow and the intertidal water. It was believed that the tide had a strong influence on dispersing and concentrating certain intertidal species and thus affected the density of the population at certain tidal levels. Results show that certain species are extremely abundant along the water's edge at low tide and become scattered to different extents in the intertidal area at high water. The D-net, which was employed in the shallow water, was too heavy to tow along the shore. It was not found possible to design an ideal net, equally efficient both in the intertidal region and the shallow water.

As a result of these difficulties, the nets used for the surface, the bottom and wading in the present work were different, and the quantitative results from the different nets have been treated separately. The D-net used on the bottom was 76 cm. in diameter with a height of 30 cm. and a length of 1.9 metres. The sides were made up of 80 cm. of canvas and 1m. of stramin (6 meshes to 1 cm.). The surface tow-net was a compound net made of coarse (10.8 meshes per cm.) and medium (20.2 threads per cm.) and fine (51.6 meshes per cm.) bolting silk, in the proportion of 52, 45, and 43 cm., and the diameter of the net was 40 cm.. The small D-net was a compound net made of canvas, stramin, mosquito net and grit gauge (13 threads per cm.) in the proportion of 9, 16, 50 and 20 cm. respectively. The diameter of the net measured 42 cm. and the height 29 cm.

All the animals obtained in the samples were sorted out from the algal fragments and the latter were weighed. Samples with large numbers of Idoteids, Gammarus and Nototropis which could not be sorted thoroughly from large quantity of algal fragments were kept damp in baths and placed under the shade. When these were filled with sea water, the animals usually swam towards the sides and were then decanted into a sieve. Repetition of this process efficiently separated the amphipods and the isopods, especially the young forms, from the weed fragments. The weed was sorted finally in an enamel tray. In cases where the animals were found to be among a small amount of algal fragments, these were preserved and then treated with a saturated solution of calcium chloride which separated the animals from foreign matter by flotation.

All organisms contained in the samples were identified and sorted into species. The individuals in each species were counted, measured, sorted into size groups and finally weighed. When the samples of certain species, such as Schistomysis spiritus, were obtained in enormous numbers, the number was estimated by counting and weighing a sub-sample and comparing this weight with the weight of the whole sample. The animals were 'dried' on blotting paper until they separated from each other. Animals up to 20 mm. were measured on a measuring board. The ovigerous females* were measured with a non-parallax scale under the dissecting microscope, the animal being straightened with a pair of forceps and a dissecting needle. The measurement was accurate to 0.5 mm. The eggs or embryos were dissected out of the brood pouch and counted. The total length of each individual in different groups was measured in different ways. Decapods and mysids were measured from tip of antennal scale to tip of telson;

* Ovigerous females refer to those females that carry eggs either in the brood pouch or on the pleopods.

Isopods were measured from antero-median border of cephalon to tip of telson, and amphipods from anter-median border of cephalon to tip of the third uropod.

The study of the diurnal movement of Crustacea Malacostraca was based on the results collected at four periods of the day, morning, daylight, evening and mid-night, during September, October and November of 1949 and from May to August of 1950. The time of sampling was different in the year and was tabulated as follows:

	Morning	Daylight	Evening	Midnight
	(Time of sampling - hours in G.M.T.)			
September-November, 1949	0800-1000	1300-1500	1800-2100	2300-0230
May - August, 1950	0400-0700	0900-1200	1600-2100	2100-0230

Crangon vulgaris Linné

General distribution and behaviour. This species is fairly abundant in the Bay throughout most part of the year. Its distribution is associated closely with a sandy substratum where it lies buried probably to escape predatory enemies and to prey upon other animals that share the same habitat. It is, as a whole, more abundant in the region which extends from low tide to mide-tide level. It appears in the intertidal area both by day and by night, and a few have occasionally been obtained after dark by wading at high water.

Some specimens obtained from the shingle bottom inside the breakwater have bolder speckles than those obtained from the sand. Kemp (1910) mentioned that specimens from mud are darker in colour than those from sand.

The behaviour of this species, as to whether it is entirely a nocturnal form which buries itself in the sand in the daytime and feeds at night, or remains partly active throughout the day, has roused arguments among different workers. Havinga (1929) states that this species buries itself in the substratum in the daytime and feeds at night. Lloyd and Yonge (1947) agree that this certainly happens in the aquarium, but their observations show there is no difference between the catches of the day and the night tides in the Bristol Channel and Severn Estuary. They believe the similarity in the catches is probably due to the exceptional turbidity of the water that nullifies the effect of light.

Observations in Port Erin Bay show that this species, especially the medium-sized individuals, is partly active during the day. It is often seen, through clear water on sunny days, walking on the sandy bottom. Under laboratory conditions where the water is still and the food supply is ample, the species buries itself in the sand in the daytime and becomes active at dusk. When a morsel of food is introduced into the aquarium in the daytime it emerges from the sand immediately and buries itself again after feeding. If the competition is intense among several individuals over the same piece of food, one will grasp the morsel, jump away at one leap and usually bury itself immediately along with the food. After being starved for several days, it is observed foraging on the sand in the daytime. It is thus reasonable to assume that this species buries itself in the sand during most part of the day and emerges occasionally in order to feed. Observations also show that most individuals crawl out from the sand and follow the water stream when the water is emptied out of the aquarium, while few remain buried. This shows that the tide might have a stimulating effect on those near the low water edge and cause them to move in and out of the intertidal area during the daytime. These observations partly explain the occurrence of this species among the samples collected along the mid-tide level in the daytime.

Stomach contents of Crangon vulgaris in the Bay show that its food consists mainly of Schistomysis spiritus throughout the year. Other inshore Amphipods, Isopods, Mysis and Polychaetes, such as Idotea sp., Gammarus locusta, Pontocrates arenarius, P. norvegicus, Glycera, Arenicola, Praunus flexuosus are also common in their stomachs.

Ehrenbaum (1890) and Havinga (1929) agree in recording that this species feeds mainly on Polychaetes. The latter finds that this species also feeds on Ulva, Enteromorpha, Gammarus, Neomysis and Corophium in brackish water. Both Havinga (1929) and Lloyd and Yonge (1947) record mollusc, fish egg and fish fry as food of Crangon vulgaris.

Seasonal abundance. Crangon vulgaris reaches its maximum in July and remains fairly abundant till November. The number reaches a minimum in December (Fig. 3).

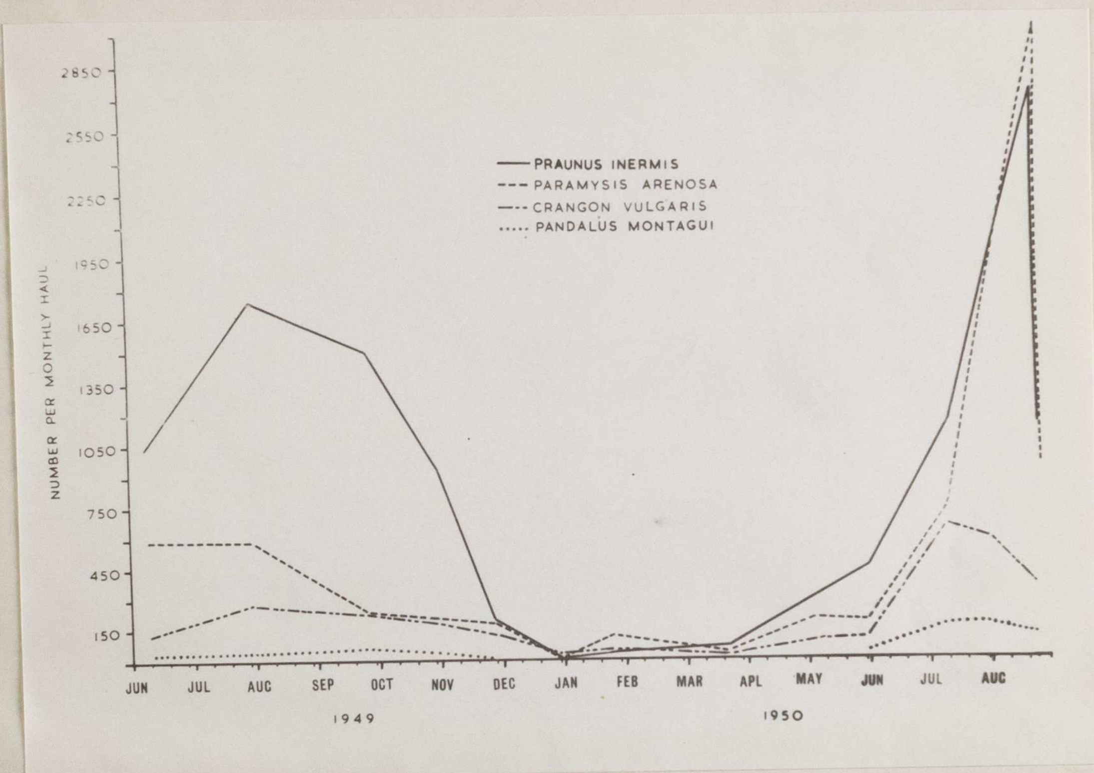


Fig. 3. Praunus inermis, Paramysis arenosa, Crangon vulgaris, and Pandalus montagui. Total number per monthly haul throughout the period June 1949 to August 1950.

Small numbers of immature forms, measuring 35-49 mm., occur in January; few of the 45-49 mm. group remain in March. The mature forms, 51-71 mm., which are remnants of the previous year, are found in the following summer months, though the number is small. The bulk of the population in the later part of the year is composed mainly of the newly-settled young forms.

The offshore migration of Crangon vulgaris in the winter and the inshore migration in the spring have been recorded by Ehrenbaun (1890), Havinga (1930) and Meyer (1935b) in the North Sea, and by Lloyd and Yonge (1947) in the Bristol Channel and Severn Estuary. The decrease in number of this species in Port Erin Bay after August and throughout the following months seems to suggest a similar off-shore migration. It is not distinctly indicated which of the size groups is the first in the offshore migration. The sudden decrease of the size groups, 30-34, 35-39 mm., however, might suggest they are the first ones to move away.. There is a general reduction in number of all size groups in the months from September to November.

Lloyd and Yonge (1947) state that migration of Crangon vulgaris in the Bristol Channel and Severn Estuary is clearly related to the low salinity and temperature. The salinity near Port Erin Bay shows a maximum of 34.24 in April and a minimum of 34.03 in October (Gilles, 1948). It is thus unlikely that low salinity is a controlling factor on the migration. The temperature (Fig. 1) and the calmness of the sea in Port Erin Bay change remarkably through autumn and winter, and thus might be factors that effect the migration.

The young forms first appear at the end of April. These young forms together with the groups that are hatched later, appear to stay and to grow in the Bay till a presumably offshore migration occurs in the winter months. The inshore migration of the individuals which have been hatched in the previous year is not ascertained except that there is a slight increase among the size groups 55-59, 60-64, 65-69 mm. in May and June.

Reproduction. Ovigerous females have been obtained in November, January, February, March, April, May, June and the early part of July. A single specimen was caught in the seine-net in the night of 17.VIII.50. The bulk of berried females was obtained in January and March. The extension of the spawning period is similar to what was found at Caroliensiel (Ehrenbaun, 1890), at Jay Bay (Meyer, 1935), and in 1940 in the Bristol Channel (Lloyd and Yonge, 1947). Both Ehrenbaun and Meyer agree that the spawning season of Crangon vulgaris can be separated into two distinct periods: the summer spawning period that extends from spring to the end of July and the winter spawning period that lasts from November to February.

The first young forms (post-larval stage), measuring around 6 mm., have been obtained in the third week of April. These larvae become abundant and constitute the bulk (90.4%) of the population in the beginning of May. It is interesting to note the closing of the gap between the size-ranges which respectively represent the young forms and the breeding individuals (Fig. 4).

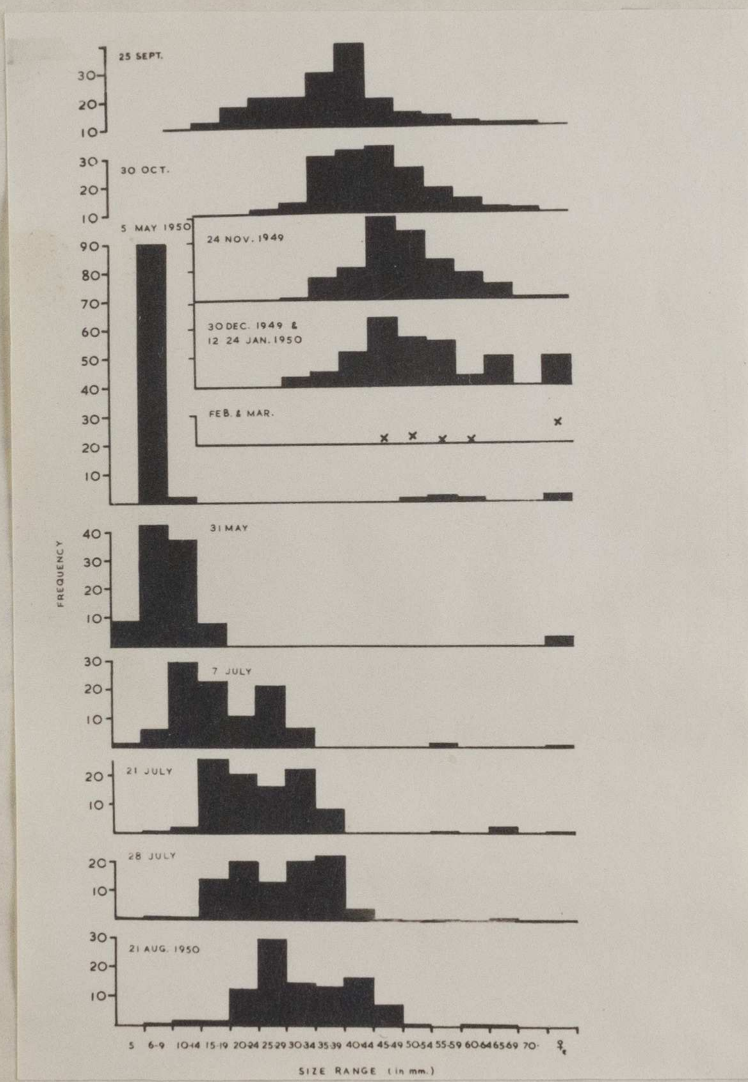


Fig. 4. The size-composition (length-frequency) of Crangon vulgaris in the samples during the period September 1949 to August 1950. X, number frequency-samples with less than 50 individuals. Block, percentage frequency-samples with more than 80 individuals.

The larvae, measuring 5mm. and 6-9 mm. occur continuously from May to the end of August, and appear to be derived from different hatching periods throughout the breeding season. The modal size groups were found to be 6-9 mm. on 5.V.50, 6-9 mm. and 10-14 mm. on 31.V.50, 10.14 mm. and 25-29 mm. on 7.V11,50, 15-19 mm. and 30-34 mm. on 21.V11.50, 20-24 mm. and 35-39 mm. on 28.V11.50, and 25-29 mm. and 40-44 mm. on 21.V111.50. The gap between the young forms and the breeding individuals, at a range of 40 mm., is completely filled up by the end of August. The size distribution in September, October, and November of 1949 represents a normal curve, with a modal size group 40-44 mm. of September and 45-49 mm. of the latter months. The modal size group of 40-49 mm. undergoes no change all through January. In summer the monthly change of the modal size group is almost at a constant rate of 4 mm., with the exception of the size groups 25-29 and 30-34 mm. in the beginning of July. The occurrence of these groups seems to be an abrupt change as compared with the advanced size group of 15-19 mm. at the end of May. This suggests the possibility of either a quick-growing group which separates from the main stock, or an inshore migration of the young forms of the previous winter. The increase in number among these groups together with the presence of the size group of 35-39 mm. at the end of July seems to favour the latter assumption. Yet, on the other hand, from the samples of November and December of 1949 and of January of 1950, that show the presence of a small number of the size group of 30-34 mm., it is unlikely that the individuals in the size groups 25-29 and 30-34 mm. are the immature forms hatched in the previous year.

Meyer (1935) estimates that the larvae, hatched in February, attain a body length of 22 mm. in July, 31 mm. in September and 37-38 mm. at the end of the first year. Havinga (1930) estimates it as 35 mm.. Lloyd and Yonge (1947) state that this species spawned in the previous year appear in June at a length between 25 and 45 mm.. It is not justified to draw any conclusion on the growth rate of Crangon vulgaris in Port Erin Bay before its inshore migration is confirmed.

Diurnal movement. The diurnal movement as shown by the difference in number between daytime and night, is not distinctly consistent, except for the samples of September, October and November when the number is consistently higher at night than in the daytime. In Table 1, it is shown that there is a common tendency to increase in number at low water edge both in the daytime and after dark.

Table 1. Crangon vulgaris.

Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day.

H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	48 (L.W.)	17 (H.W.)	63 (L.W.)	103 (H.W.)
30 Oct.	20 (H.W.)	39 (L.W.)	37 (H.W.)	86 (L.W.)
24-25 Nov.	11 (L.W.)	18 (H.W.)	32 (L.W.)	63 (H.W.)
1950				
4 May	46 (L.W.)	12 (H.W.)	5 (L.W.)	21 (H.W.)
31 May	32 (L.W.)	13 (H.W.)	15 (L.W.)	39 (H.W.)
7 July	70 (H.W.)	128 (L.W.)	65 (H.W.)	no sample
21 July	-	-	-	406 (L.W.)
28 July	104 (L.W.)	58 (H.W.)	304 (L.W.)	126 (H.W.)
21 Aug.	83 (H.W.)	136 (L.W.)	69 (H.W.)	83 (L.W.)

Apparently, the tide strongly influences the dispersal and concentration of this species in the tidal area. The inconsistent change in number of the population between day and night is probably due to the occasional activity of this species during the day and to the D-net that sometimes digs into the substratum and thus catches animals which would not necessarily be active.

Philocheras trispinosus (Hailstone)

Common. This species tends to be more abundant along the Raglan Pier from May to September and in the region from Raglan Pier to the life-boat slip in the remainder of the year. It moves occasionally to the intertidal area after dark; none has been taken along the high water edge. Like Crangon, this species prefers to bury itself in the sand in the daytime, by means of the pereiopods.

Seasonal abundance. P. trispinosus reaches its maximum abundance in October, decreases sharply in November, and becomes rare in December (Fig. 5).

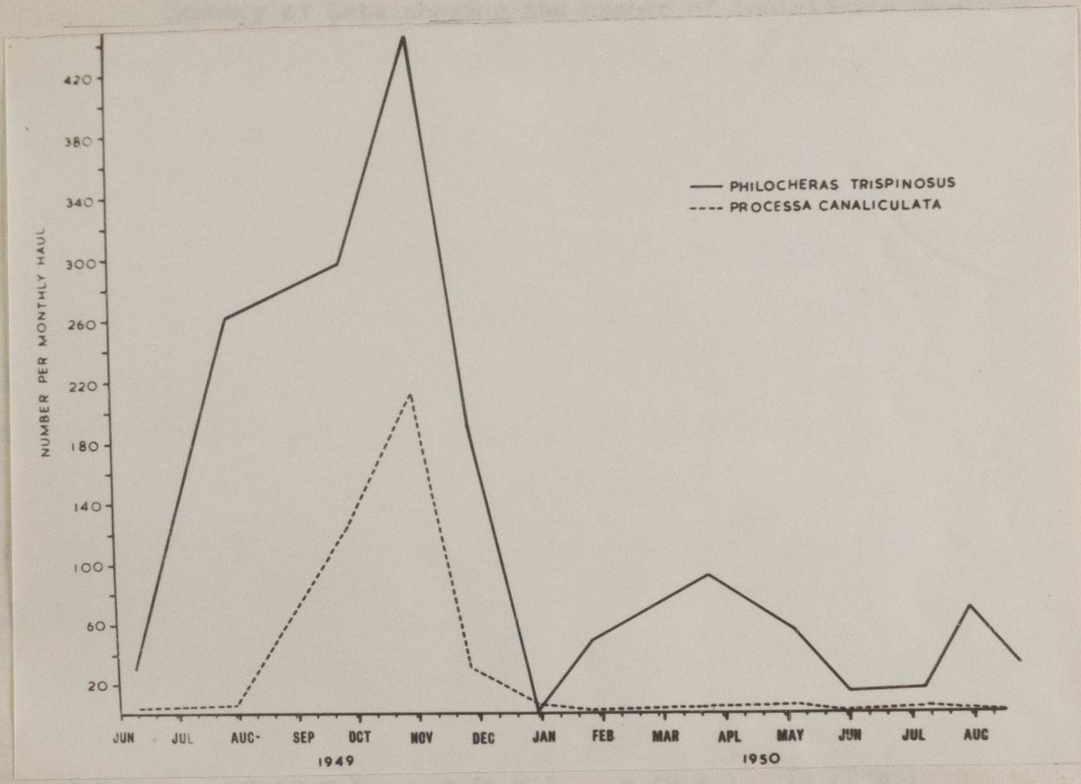


Fig. 5. Philocheras trispinosus and Processa canaliculata per monthly haul throughout the period June 1949 to August 1950.

The nature of the sudden decrease toward winter is not understood. The increase in number in the shallow water in October and November seems to suggest a seaward movement. The species shows a marked increase in January, and is more abundant in the shallow water than in the adjacent region of the intertidal area. The number in the months from March to August of 1950 remains few and shows remarkable fluctuation.

The number obtained in July and August of 1949 is considerably higher than in the corresponding period of 1950.

Reproduction. Ovigerous females have been obtained in January, March, May, June, July and August, the bulk being obtained in March and in the beginning of May.

The first young forms, measuring 5-9 mm., were obtained on 7.V11.50. These remained few in the summer of 195o.

Diurnal movement. More are caught by night than by day (Table 2).

Table 2. *Philocheras trispinosus*.

Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day.

H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	108 (L.W.)	6 (H.W.)	97 (L.W.)	86 (H.W.)
30 Oct.	21 (H.W.)	34 (L.W.)	166 (H.W.)	219 (L.W.)
24-25 Nov.	2 (L.W.)	17 (H.W.)	129 (L.W.)	45 (H.W.)
1950				
4 May	15 (L.W.)	1 (H.W.)	14 (L.W.)	25 (H.W.)
31 May	13 (L.W.)	0 (H.W.)	1 (L.W.)	1 (H.W.)
7 July	3 (H.W.)	5 (L.W.)	2 (H.W.)	12 (L.W.)
28 July	27 (L.W.)	12 (H.W.)	5 (L.W.)	24 (H.W.)
21 Aug.	5 (H.W.)	4(L.W.)	3 (H.W.)	19 (L.W.)

It is likely that this species is more consistent in its instinct of burying itself in the sand in the daytime and becoming active after dark than is Crangon vulgaris. The graphs further show that in some samples, 26.IX.49, 4.V.50, 31.V.50, 28.VII.50, the number increases at low water in the early morning. Evidently, this species remains active in its habitat in the early morning.

Other Philocheras spp.

Philocheras bispinosus (Hailstone)

This species occurred in the samples of September, October and November of 1949. 16 specimens have been obtained after midnight and 3 in the early morning in the shallow water. Kemp (1910) remarks that this species is abundant all along the Irish coast and is distributed at all depths, descending to as much as 200 fathoms of water. One ovigerous female was obtained on 26.IX.50 inside the breakwater.

Philocheras sculptus (Bell)

Rare. 2 occurred in the midnight sample of 25.IX.49 and 5 in the afternoon sample of 26.IX.49 and one ovigerous female on 21.VIII.50. All the specimens were obtained from shallow water.

Philocheras faciatus (Risso)

This species is commoner than P.bispinosus and P. sculptus. Few specimens are present in the samples of all months, except of October and December. 24 specimens have been obtained in the night samples and 5 during the daytime. All the specimens, except 3 collected from the area adjacent to the intertidal region , were obtained from the shallow water.

3 ovigerous females were obtained on 21.VII and 21.VIII of 1950 and measured 22, 21 and 14 mm. respectively.

This species is widely distributed off the Irish Coast, but not common at any particular locality and has not been taken below more than 15 fathoms (Kemp, 1910).

Leander serratus (Pennant)

This species occurs in all months except December. It occurs chiefly in the area extending from the south corner of the breakwater to the life-boat slip. It is also common in the rock pools near Spaldrick in the summer months, becoming rare in winter. The specimens obtained from the shallow water region are provided with red chromatophorea which in those obtained from the rock pools are either pale or bluish green in colour. No ovigerous females have been obtained from the shallow water though these are common in the rock pools in June.

The difference in number between the day and the night catches is not marked. A single young form measuring 10 mm. has been obtained along the low water edge after dark.

Processa canaliculata Leach

General distribution and behaviour This species was fairly abundant in the months of September, October and November of 1949, and few or rare from then until August in 1950. Most of the specimens were obtained from the shallow water after dark, few having been obtained in this region in the daytime of the winter months, and none in the summer months. A single specimen was obtained along the mid-tide level after dark on September 25th, 1949. Kemp (1910) states that this species appears to be most abundant between 20 and 40 fathoms off the Irish Coast. It has been recorded in the Mediterranean from a depth of 326 fathoms (Adensamer, 1898). Obviously Processa canaliculata is an inhabitant in deeper water. Gurney (1923) observed living specimens in aquaria provided with stones and found them always quiescent and wedged between the stones during the daytime. He also states that Processa shows no inclination to burrow in sand. Judging from Gurney's observation and the sandy substratum in the Bay, it is very likely that the occurrence of this species in the Bay is a result of its extensive nocturnal excursion when it presumably moves shoreward to the shallow water after dark and moves seaward to the deeper water in the daytime.

Seasonal abundance This species shows a sudden increase in number in September and reaches its maximum in October when two series of night hauls obtained 204 individuals (30.X.49). It remains few or rare in the remainder of the year (Fig. 5). The young forms, 5-9, 10-14, 15-19 mm., predominate in October.

Reproduction Ovigerous females are extremely rare; specimens have been obtained in March, June and July.

Diurnal movement   As shown in Table 3, the number obtained at night is notably higher than in the daytime.

Table 3. Processa canaliculata.

Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day.

H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	2 (L.W.)	2 (H.W.)	50 (L.W.)	67 (H.W.)
30 Oct.	1 (H.W.)	8 (L.W.)	81 (H.W.)	123 (L.W.)
24-25 Nov.	1 (L.W.)	0 (H.W.)	14 (L.W.)	15 (H.W.)
1950				
4 May	0 (L.W.)	0 (H.W.)	0 (L.W.)	5 (H.W.)
31 May	0 (L.W.)	0 (H.W.)	0 (L.W.)	1 (H.W.)
7 July	0 (H.W.)	0 (L.W.)	0 (H.W.)	4 (L.W.)
28 July	0 (L.W.)	0 (H.W.)	0 (L.W.)	2 (H.W.)
21 Aug.	0 (H.W.)	0 (L.W.)	0 (H.W.)	1 (L.W.)

The specimens caught in the daytime in September, October and November were mostly young forms, measuring 15-16 mm. but there were none during the summer months. The population tends to scatter in all regions at midnight from mid-tide level to shallow water, and is most abundant inside the breakwater. In the samples of October and November, the number is highest along the life-boat slip and the population as a whole shows a slight increase in number at midnight.

Russell (1925) found no marked vertical movement of post-larval Processa throughout the period from daylight to daylight, but it was always present in large numbers below 7 metres.

Jourdain (1878) and Gurney (1923) studied the effect of light on colour changes in Processa, and drew the conclusion that light causes the contraction of pigments of chromatophores. These experiments indicate that light has certain physiological effect on Processa, but shed no light on the factors influencing its nocturnal movement.

Pandalus montagui (Leach)

General distribution This species is common in shallow water in the months from May to November, and absent for the remainder of the year. Small numbers have been obtained along the Raglan Pier after dark and a single specimen was obtained in the intertidal zone on 30.X.49 after dark. The occurrence of this species seems to be correlated with the presence of algal fragments. Hjort and Ruud (1938) state that Pandalus occurs in greatest abundance in situations where the bottom waters are sufficiently quiescent for organic debris to settle to the bottom.

Murie (1903) and Kemp (1910) describe a gregarious inshore migration of this species in late spring, and an offshore spawning migration in November and December.

The first occurrence of Pandalus montagui in Port Erin Bay is shown by the presence of small numbers of post-larval young forms, measuring 10-11 mm. on 23.V.50. These larvae continue to stay and grow till the end of November. The modal size-group is found to be 10-14 mm. on May 31st, 20-24 mm. on July 7th, 30-34 mm. on July 28th, and 35-39 mm. on August 21st of 1950, and 45-49 mm. on September 24th and October 30th of 1949. A single specimen obtained in October 1949 measured 56 mm; two specimens obtained in November measured 50 mm. (Fig. 6).

No ovigerous females have been obtained in the Bay, nor is there any sign of breeding in the period of the offshore migration.

Seasonal abundance This species in the Bay reaches its maximum at the end of September of 1949 and July of 1950, and remains abundant in August and September and decreases sharply in October and November. It is absent in the Bay in the months from December to the early part of May (Fig. 3).

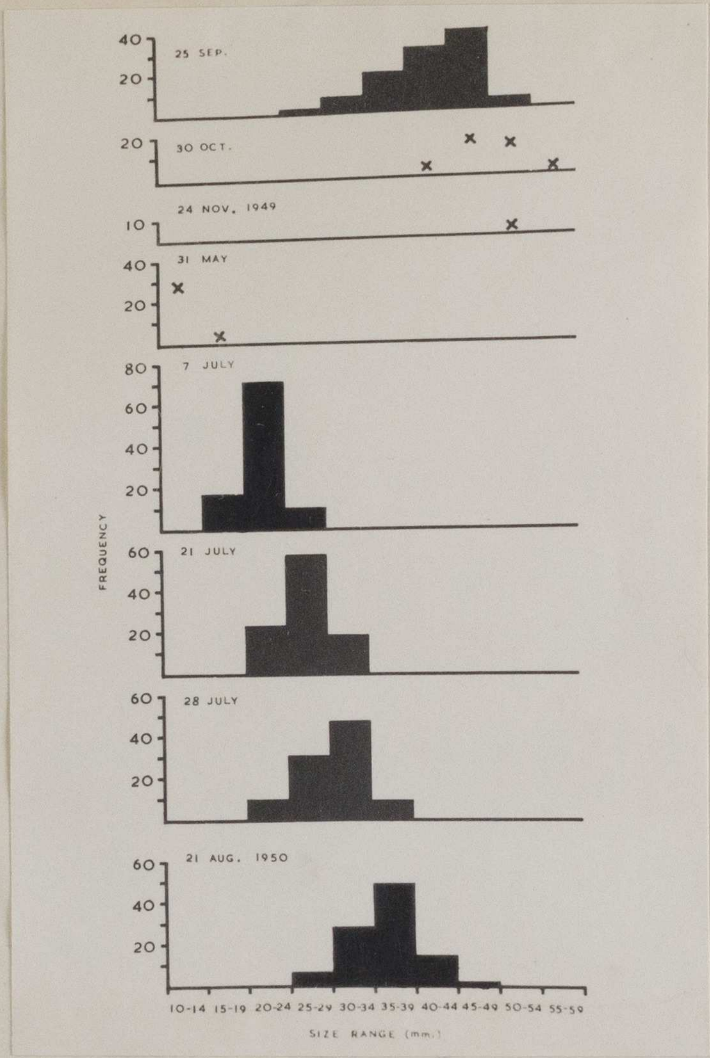


Fig. 6. The size-composition (length-frequency) of Pandalus montagui in the samples during the period September 1949 to August 1950. X - number-frequency samples with less than 50 individuals. Block - percentage-frequency samples with more than 50 individuals.

Diurnal movement. The number shows a tendency to be higher at night than in the daytime (Table 4).

Table 4. Pandalus montagui.

Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day.

H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	6 (L.W.)	4 (H.W.)	21 (L.W.)	7 (H.W.)
30 Oct.	3 (H.W.)	6 (L.W.)	12 (H.W.)	10 (L.W.)
24-25 Nov.	0 (L.W.)	0 (H.W.)	2 (L.W.)	0 (H.W.)
1950				
4 May				
31 May	8 (L.W.)	3 (H.W.)	18 (L.W.)	2 (H.W.)
7 July	25 (H.W.)	38 (L.W.)	11 (H.W.)	no sample
21 July	-	-	-	83 (L.W.)
28 July	22 (L.W.)	36 (H.W.)	40 (L.W.)	64 (H.W.)
21 Aug.	21 (H.W.)	22 (L.W.)	25 (H.W.)	45 (L.W.)

Russell (1925) finds that there is no marked diurnal movement in the post-larvae of Pandalus sp. Larvae never appear in numbers in the surface layers, but always in large numbers below 7 metres.

Athanas nitescens (Montagu)

This species occurs only occasionally ~~and~~ in the samples for November and March. It is more numerous along the littoral zone along the south side of the Bay. A single young specimen measuring 4.5 mm. has been obtained by wading at low water after dark.

Hippolyte varians Leach

Hippolyte varians is common in all regions below the low water mark and is abundant in the shallow water in the region between the life-boat slip and the breakwater. Few have been obtained between tide marks either in the daytime or at night; none is recorded by wading along the water's edge at both high and low tides. This species, as Kemp (1910) states, is abundant between tidal marks and down to 25 fathoms along the Irish coast and a single specimen has been dredged between 110 and 130 fathoms, though it is scarce in deep water.

Seasonal abundance   Hippolyte varians reaches its maximum abundance in September, remains abundant in October, and decreases sharply in November till it falls to a minimum in December (Fig. 7).

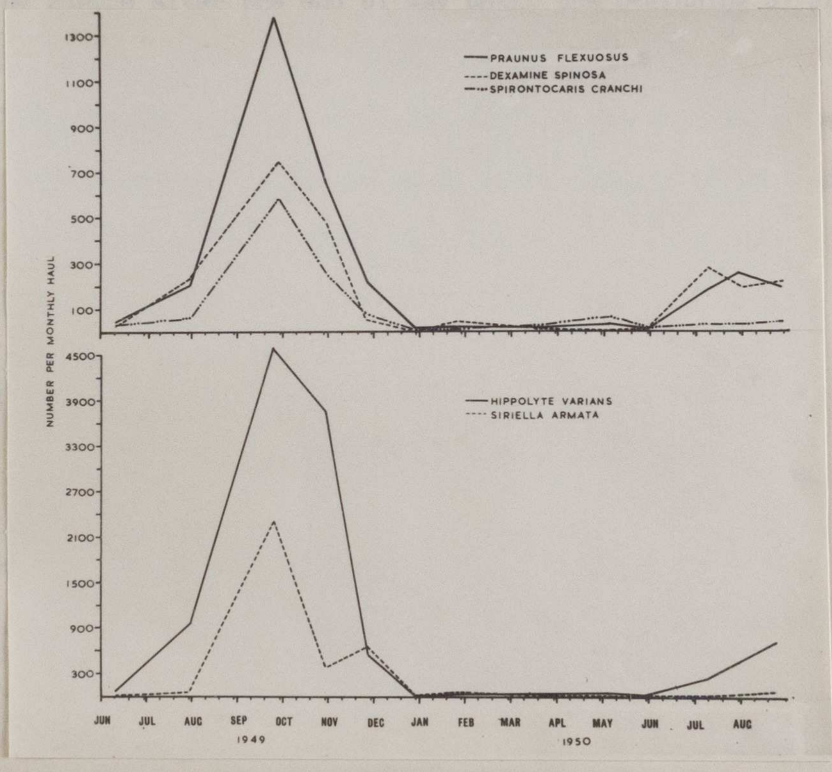


Fig. 7. Praunus flexuosus, Dexamine spinosa, Spirontocaris cranchi, Hippolyte varians, Siriella armata. Total number per monthly haul throughout the period June 1949 to August 1950.

The maximum is marked by the predominance of young forms of two size groups, 6-10 and 13-16 mm. All the size groups increase in number in October except the young forms 6-10 mm. which show a sharp decrease.

The number shows a general decrease in all size groups in November, more markedly among the size group 6-10 mm. which is reduced to a small number of 83 as compared with the maximum number of 1955 in September. The number increases slightly from January to May, with a constant modal size group of 13-16 mm. The number of the population shows a marked increase in July and August when the young forms become abundant and predominate.

Reproduction Ovigerous females have been obtained from March to September, the bulk being collected in August and September. The first young forms, measuring 6-9 mm., appear in the sample on 9.VI.49. Poor weather interrupted the work in June of 1950, so there is no sample after the end of May until the beginning of July.

Table 5. Hippolyte varians. Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day.

H.W. High Water; L.W. Low Water

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	585 (L.W.)	306 (H.W.)	2359 (L.W.)	1342 (H.W.)
30 Oct.	259 (H.W.)	476 (L.W.)	1497 (H.W.)	1530 (L.W.)
24-25 Nov.	119 (L.W.)	75 (H.W.)	220 (L.W.)	171 (H.W.)
1950				
4 May	9 (L.W.)	13 (H.W.)	4 (L.W.)	63 (H.W.)
31 May	6 (L.W.)	7 (H.W.)	5 (L.W.)	1 (H.W.)
7 July	44 (H.W.)	56 (L.W.)	40 (H.W.)	102 (L.W.)
28 July	84 (L.W.)	84 (H.W.)	144 (L.W.)	130 (H.W.)
21 Aug.	194 (H.W.)	208 (L.W.)	184 (H.W.)	149 (L.W.)

Diurnal movement As shown in Table 5, the numbers in the months of September, October and November are consistently higher after dark than in the daytime. There is a distinct increase in number in the shallow water and in the region adjacent to the intertidal area after dark. The change is not distinct in the summer months, except that in the samples of 7.VII.50 and 4V.50, there is an increase of number after dark and an increase in the evening in the sample of 28.VII.50.

A vertical movement is shown only among the young forms. Small numbers, measuring 6-7 mm., have been obtained in the surface tow-net in all regions of the Bay in May, July, August and September. The number obtained on the surface is insignificant as compared with the number of the same size group obtained from the bottom.

<u>Spirontocaris cranchi</u> (Leach)

Common. The distribution of this species, similar to that of <u>Hippolyte varians</u>, is confined to shallow water. It is found along the sub-littoral zone at the north and the south side of the Bay where the ground is rocky and rich in algae. A single specimen was obtained along the mid-tide level after dark on 31.V.50.

<u>Seasonal abundance</u> From Fig. 7, this species increases suddenly till it reaches its maximum in September, remains abundant in October and decreases markedly in November. The maximum number consists mainly of young forms (61.6%), measuring 6-9 mm. The change in the later months among the population as regards the size shows similar characteristics to that of <u>Hippolyte varians</u>, in the marked decrease of the young forms 6-9 mm., and the slight change among the bigger sized groups in October and a general decrease of all size groups in November. The number reaches its minimum in December and January. The population remains small from March till August. Ovigerous females occur in the samples of the beginning of May. The number of young forms does not become conspicuous till the end of August.

<u>Reproduction</u> Ovigerous females have been obtained in May, June, July, August and September. The number of berried females is higher in May than in the later months of the breeding season.

The young forms are rare in May and June of 1950. The number shows an increase at the end of August.

Diurnal movement The number caught, as shown in Table 6, is persistently higher after dark than in the daytime, both in winter and summer months. In the months of September, October and November, the species shows a marked increase from 72.1% to 89.1% after dark, and in the months from May to August the night hauls are invariably higher (14.6% to 100%) than the day hauls.

Table 6. Spirontocaris cranchi

Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day.

H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	25 (L.W.)	9 (H.W.)	268 (L.W.)	284 (H.W.)
30 Oct.	2 (H.W.)	12 (L.W.)	128 (H.W.)	116 (L.W.)
24-25 Nov.	8 (L.W.)	3 (H.W.)	33 (L.W.)	35 (H.W.)
1950				
4 May	2 (L.W.)	0 (H.W.)	0 (L.W.)	65 (H.W.)
31 May	2 (L.W.)	2 (H.W.)	4 (L.W.)	10 (H.W.)
7 July	0 (H.W.)	0 (L.W.)	1 (H.W.)	29 (L.W.)
28 July	3 (L.W.)	1 (H.W.)	0 (L.W.)	19 (H.W.)
21 Aug.	13 (H.W.)	7 (L.W.)	2 (H.W.)	19 (L.W.)

The samples of 21.VIII.50 show a considerably higher number in the early morning than at any other time during the day. Samples obtained along the rough ground on the north and the south side of the Bay in the daytime show higher numbers than those obtained from rocky shallow water. It is assumed that this species might move to the sublittoral zone in the daytime and move to the shallow water after dark.

Praunus flexuosus (Müller)

This species is common in all regions at low water mark and in shallow water, and is abundant in the latter part of the year. It also moves into the intertidal area. Small numbers of young forms have been obtained along the water's edge at all states of the tide, both by day and by night. The number of individuals of all size groups increases along the water's edge, especially along the low water mark, in September, October and November. A small number of mature females, measuring 26 mm., have been obtained in December, and ovigerous females in January along high water edge.

Individuals have been frequently observed swimming a few inches above the fucoid plants which grow on the wall of the Raglan Pier. Although their swimming is almost incessant, these mysids stay almost in the same spot. This species seems to prefer rocky ground which is rich in algae.

Seasonal abundance   The number increases gradually from the latter part of June, and reaches its maximum in September (Fig. 7). The population in the months from July to October is composed mainly of young forms, 6-8 and 9-12 mm., consisting of all stages of maturity from newly-hatched young forms to those that begin to show the secondary sexual characters.

Reproduction   Blegvad (1922) studied the general biology of *Praunus flexuosus* at Copenhagen and sorted the population, especially the breeding individuals, into two stocks: (i) winter stock; these were hatched in the previous year, reached maturity in the late spring, started to breed from the middle of May, and gradually died off in the course of July and August. The average size of the ovigerous females of the winter stock was 24 mm. (ii) summer stock, the offspring of the winter stock (or of the first generation of early hatched summer stock). Some of the early hatched young forms reached maturity in July and started to breed, but the majority remained immature and passed into the winter stock. The summer stock were considerably smaller; the ovigerous female averaged 17.9 mm.

The ovigerous females of this species in Port Erin Bay belong to 3 distinct size groups which appear at different periods of the breeding season. It is clearly shown in Fig. 8 that each group occurs almost during a period of two months, with a one month interval in between during which there are found both the survivors of the older group and the appearance of the new.

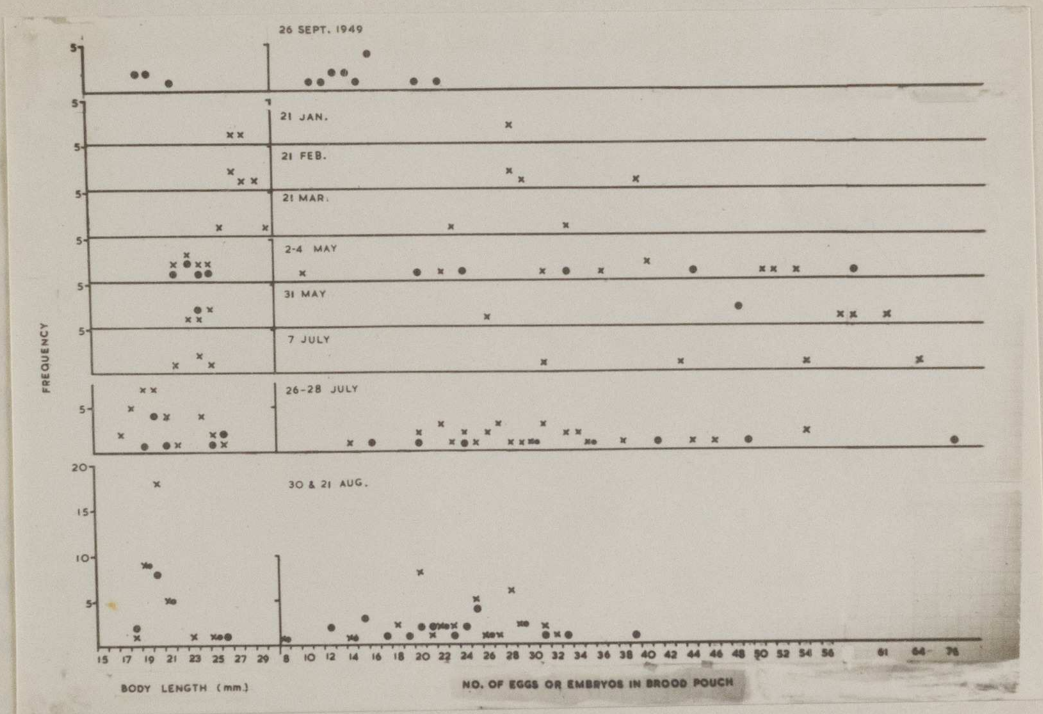


Fig. 8. Praunus flexuosus. Diagram showing the size composition of the ovigerous females and the number of eggs or embryos in the brood-pouch throughout the months of the breeding period. ● - samples collected in 1949.

X - samples collected in 1950.

Frequency indicates the number.

It is assumed, according to Blegvad's theory, that the groups that occur in January-February and May-June are winter stock which reach maturity at different periods of the season. This assumption is substantiated by the occurrence of large non-ovigerous females, measuring 25-26 mm. in November when the breeding season is at an end. These females survive in December and January of the following year, decrease considerably in February and disappear completely in March. The number of the ovigerous females, on the other hand, increases from January to

March, indicating that the mature females of the former month start to spawn in the latter month. It is also noted that females measuring 22-24 mm. in the winter months show no signs of breeding in March. The disappearance of these females in the beginning of May corresponds exactly with the occurrence of the ovigerous females of the same size at the same time. The source of the ovigerous females in the latter part of July and August is not clear. It seems that the ovigerous females found in the latter part of the breeding season are mainly summer stock which are hatched in May or June. From Fig. 13 it is shown that the ovigerous females collected in July and August are divided into a main group of smaller size and a lesser group of bigger size. The latter group belongs probably to the remnants of the winter stock.

Blegvad (1922) states that the number of eggs or embryos in the brood-pouch increases with the body length of the ovigerous females, collected on the same date. Results of the correlation between the size and the fecundity of this species at Port Erin Bay show great flexibility as regards individuals, but the difference of fecundity on the average shows a tendency to increase with the increase of the body length. (Table 8).

As shown in Fig. 8, it is apparent that fecundity shows close correlation with season, irrespective of body length of the ovigerous females. In January and February, the ovigerous females reach the maximum size, 27-29 mm., in the year and contrarily bear the minimum number of eggs and embryos. In May the number of eggs increases as the size of the ovigerous females decreases, and in August both the fecundity and the size decrease.

It is noteworthy that all the ovigerous females in the winter months have been obtained along the water's edge at both high and low water, but in the summer months these are obtained exclusively from shallow water. The first young forms, measuring around 7 mm., were obtained on 4.V.50.

The size distribution of this species in May shows at either end ovigerous females and young forms, which represent respectively the winter and the summer stocks. The individuals in the gap are two mature males of the winter stock. The gap is gradually filled up by the growing young forms in the following months till the end of September.

Diurnal movement As shown in Table 7, this species does not perform regular diurnal movement.

Table 7. Praunus flexuosus. Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day.

H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	454 (L.W.)	234 (H.W.)	439 (L.W.)	167 (H.W.)
30 Oct.	101 (H.W.)	87 (L.W.)	137 (H.W.)	334 (L.W.)
24-25 Nov.	85 (L.W.)	58 (H.W.)	69 (L.W.)	12 (H.W.)
1950				
4 May	15 (L.W.)	2 (H.W.)	5 (L.W.)	4 (H.W.)
31 May	8 (L.W.)	2 (H.W.)	3 (L.W.)	4 (H.W.)
7 July	46 (H.W.)	47 (L.W.)	63 (H.W.)	24 (L.W.)
28 July	50 (L.W.)	27 (H.W.)	102 (L.W.)	75 (H.W.)
21 Aug.	40 (H.W.)	69 (L.W.)	72 (H.W.)	13 (L.W.)

The irregularities in numbers in the samples can be partly explained by the habit of this species of swimming at various depths from the bottom. The numbers in the samples of the same date depend greatly on the course of the dragging and the vertical distribution of this species.

Praunus inermis (Rathke)

Praunus inermis occurs in the shallow water and is abundant along the life-boat slip. Both young forms and ovigerous females have been obtained between tide-marks, more often at night. One individual, measuring 10 mm., was caught along high water mark after midnight on 31.V,50.

Seasonal abundance   This species reaches its maximum in July, remains abundant till October and decreases markedly in November and becomes rare in December and January (Fig. 3); the number increases again in March, when the population is composed almost entirely of mature forms and ovigerous females. The young forms increase markedly in the beginning of May though the ovigerous females are the highest in number among all the size groups in the beginning of July. This leads to the maximum abundance of the population at the end of July, when the young forms predominate.

Reproduction   Ovigerous females have been obtained in all months throughout the year, though the number is considerably higher in June, July, August and September.

Blegvad (1922) sorts the population of Praunus inermis in Danish water into the winter and the summer stocks in the same way as Praunus flexuosus. He distinguished the two groups upon the bases of body length, coloration, and the period of the breeding season. He finds that the average length of the ovigerous females of the winter stock is 13.6 mm. and that of the summer stock is 10.4 mm. The breeding season of the winter stock, as he estimated, lasted from April to August, and that of the summer stock from July to October.

As shown in Fig. 9, the breeding population is composed of different size groups. In May the size of the ovigerous females ranges from 14 to 17 mm. and the modal size group changes from 15 to 16 mm. from the beginning to the end of the month. In July the size varies from 12 to 18 mm. and the modal size group changes from 14 to 15 mm. from the beginning toward the end of the month. The occurrence of the

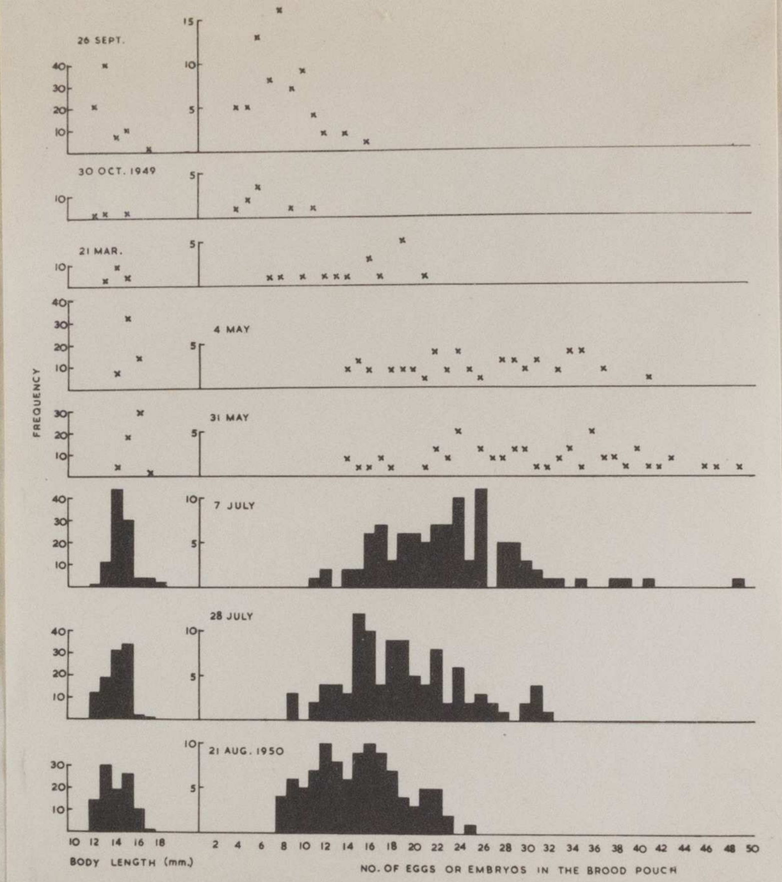


Fig. 9. Praunus inermis. Diagram showing the size composition of the ovigerous females and the number of eggs or embryos in the brood-pouch throughout the months of the breeding period, September 1949 to August 1950. X number frequency - samples with less than 100 individuals. Block, percentage frequency - samples with 100 individuals.

smaller ovigerous females of 12 mm. and 13 mm. which are absent in the previous months, and the decrease in length of the modal size group, suggest the entry of new groups. The suggestion finds further proof in the sudden increase of the ovigerous females in July. This increase is more marked in August and September when the small ovigerous females, 13 mm., become the dominant size group.

The ovigerous females seem to grow during the spawning period. It is shown in the bigger size of the spent females. The same tendency is shown in the histogram in the general increase in body length of the ovigerous females from March to May and from the beginning to the end of July.

Studies in the size distribution of the ovigerous females of Praunus inermis at Port Erin Bay suggest the existence of different groups, probably a winter stock in the early months and a summer stock in the latter months. It is supposed that overlapping occurs during the period of July and August. In such a case, it is found that the body length cannot be used to separate the individuals into winter and summer stocks, as the body length in the same group varies to a certain degree; nor can the modal size group of the body length of the ovigerous females be regarded as a satisfactory basis for the separation. The modal size group of the ovigerous females, as shown in Fig. 8, alternates between 14 and 16 mm. from March to July; those individuals in March and at the beginning of July share the same modal group of 14 mm. and those at the beginning of May and at the end of July share the modal size group of 15 mm., though the ovigerous females of these two months might belong to different stocks. The difference of the modal size groups between the winter and the summer stocks is thus not traceable till September and October, when, as has just been mentioned, most of the ovigerous females become distinctly small (13 mm.) as compared with those in May (15 mm. and 16 mm.). The nature of the ovigerous females, therefore, remains obscure. It is only through comparison made among a considerable number of ovigerous females collected successively during a period of several months, that the existence of the two stocks can be noted.

Apstein (1906) worked on Mysis mixta in the Baltic, and Blegvad (1922) on Praunus flexuosus and P. inermis in Danish waters. Both agree that fecundity depends partly on the size of the females and partly on the time of the year. From Table 8 it is apparent that the fecundity agrees with the difference of the body length of the ovigerous females collected on the same date; the larger the females, the higher the number of eggs or embryos. However, both Fig. 8 and Table 8 show that the potentialities of the reproduction is in closer correlation with the change of the season than with the size of the females. As shown in Fig. 9, it is clear that the maximum number of eggs or embryos occurs in May and at the beginning of July in spite of the difference in size of the ovigerous females and the nature of the breeding stock.

Table 8 RELATION OF SIZE OF OVIGEROUS FEMALES AND NUMBER OF EGGS OR EMBRYOS IN THE BROOD POUCH

(A) Number of individuals (B) Average number of eggs

Species	Schistomysis spiritus										Paramysis arenosa		Praunus inermis						P. flexuosus		Siriella armata			
Date	26.v.50		30.ix.50		30.x.50		30.xi.50		9.xii.50		21.viii.50		4.v.50		31.v.50		21.viii.50		21.viii.50		21.viii.49		26.ix.49	
Body Length (mm.)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
6											6	7.2												
7											40	8.4												
8											16	10.7												
9											3	11												
10			4	5.7																				
11			57	6.8	28	6	32	5.6	13	3.6							1	9						
12	4	13.5	24	8.0	55	6.8	53	6.2	66	4.4							14	10.5						
13	10	16.4	15	10.5	14	8.6	13	7.5	21	5.3							30	12.7						
14	51	17.9			3	11	1	9.0					4	23.2	1	28	19	15.2						
15	34	18.7					1	10					9	29.5	14	29.7	26	17.6						
16	1	17											1	37	21	32.3	10	20.7						
17															1	36	1	21						
18																			3	14.5				
19																			18	19.8				
20																			26	24.2	5	37		
21																			10	24.4	12	43.2	4	30
22																			2	31.0	9	53.4	2	48
23																			1	25			1	34
24																					3	69.7	2	49
25																			1	29				
26																			1	26				
27																					2	99		

In the Table 8 it is seen that the potentialities show a sharp decrease in August; ovigerous females of the sizes of 14, 15 and 16 mm. produce respectively 28, 29.7 and 32.3 eggs or embryos in May, but in August ovigerous females of the same sizes produce respectively 15.2, 17.6 and 20.7 eggs or embryos.

Diurnal movement As shown in Table 9, the serial samples, except on September 24, October 30 of 1949, and July 28 of 1950, show slight change in number between the daytime and the night.

Table 9. Praunus inermis. Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day.

H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	257 (L.W.)	238 (H.W.)	694 (L.W.)	254 (H.W.)
30 Oct.	37 (H.W.)	129 (L.W.)	356 (H.W.)	409 (L.W.)
24-25 Nov.	34 (L.W.)	29 (H.W.)	88 (L.W.)	18 (H.W.)
1950				
4 May	167 (L.W.)	30 (H.W.)	43 (L.W.)	73 (H.W.)
31 May	213 (L.W.)	34 (H.W.)	196 (L.W.)	17 (H.W.)
7 July	482 (H.W.)	236 (L.W.)	218 (H.W.)	226 (L.W.)
28 July	518 (L.W.)	173 (H.W.)	649 (L.W.)	1429 (H.W.)
21 Aug.	381 (H.W.)	266 (L.W.)	421 (H.W.)	60 (L.W.)

The higher number in the samples after dark in September, October and July probably indicate that (i) the immature forms keep close to the bottom after dark and move away from the bottom layer in the daytime; or (ii) it might be but a random result since Praunus inermis is supposed to be gregarious to a certain extent and swims close to the bottom; the number in the sample might mainly depend on the course of the net and the location of a shoal.

Siriella armata (M. - Edwards)

General distribution This species occurs at all regions below low water mark in the Bay. Large numbers have often been observed swimming slowly at all depths along the Raglan Pier, especially on calm sunny days in September. It also moves, from September to October, to the inter-tidal region, and large number of young forms, measuring 9-12 mm., have been caught by wading at high water in September both in the daytime and at night.

Seasonal abundance The seasonal frequency shows a maximum in September (Fig. 7), decreases sharply in October and again shows a slight increase in November. The maximum numbers in September consist principally of young forms, with a smaller number of non-breeding adults and few ovigerous females. The presence of ovigerous females in September indicates a possible relationship with the reappearance of the young forms in November. Small numbers of all size groups remain throughout the winter months. The individuals which have passed the winter months are almost absent from March to early June, as indicated by the average catches in the monthly samples, which have never exceeded 4 specimens in those months. Fage (1933) has shown:
"A Concarneau le Siriella armata n'est jamais très abondant; la pêche la plus nombreuse se chiffre par 24 individus adultes. Mais on peut le prendre sporadiquement à tous les mois de l'année. Nos pêches indiquent néanmoins que son maximum d'abondance dans le plancton de nuit peut être fixé de la fin de septembre au debut de mars."
The reason of the scarcity of Siriella armata in the spring and the early summer months in Port Erin Bay is unknown. It is possible that the mortality of the young forms is high under the unfavourable conditions in the previous winter or an offshore migration follows immediately after the swarming in September, when most of the young forms are driven to the deeper water where the conditions are more favourable.

Reproduction Ovigerous females were obtained from January to November. The number of ovigerous females is very small from January to the end of July, and not at all comparable to the high numbers in August, September and November. It seems that the small number of the former months is related to the individuals which have passed the winter and, hence, corresponds to the winter stock of Praunus. The ovigerous females of the latter months are supposed to be summer stock, the offspring of the winter breeders, and reach maturity in August.

The first young forms appear in the beginning of May. The size-distribution (Appendix) of the specimens obtained in May is marked by the two extremities which represent the distribution of the adults and the newly-hatched young individuals. The growing young forms fill up the gap and many reach maturity by the end of August.

As is shown in Table 10, it is clear that Siriella armata perform diurnal vertical movements.

Table 10. Siriella armata.
Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day.
H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	992 (L.W.)	1124 (H.W.)	33 (L.W.)	178 (H.W.)
30 Oct.	193 (H.W.)	193 (L.W.)	18 (H.W.)	0 (L.W.)
24-25 Nov.	137 (L.W.)	512 (H.W.)	3 (L.W.)	0 (H.W.)
1950				
4 May	2 (L.W.)	1 (H.W.)	0 (L.W.)	0 (H.W.)
31 May	1 (L.W.)	3 (H.W.)	1 (L.W.)	0 (H.W.)
7 July	6 (H.W.)	5 (L.W.)	5 (H.W.)	0 (L.W.)
28 July	9 (L.W.)	2 (H.W.)	26 (L.W.)	4 (H.W.)
21 Aug.	15 (H.W.)	41 (L.W.)	21 (H.W.)	2 (L.W.)

It appears near the bottom in large numbers in the daytime and becomes few in the bottom layer at night. Many young forms have been obtained along the water's edge at night, and only young specimens were caught in the surface tow-net after dark on August 21st, 1950. It is reasonable to believe that this species must be scattered at all depths below the surface after dark.

Siriella jaltensis Czerniavsky

General distribution This species does not seem to be a permanent resident in Port Erin Bay. Its occurrence during the autumn and winter months is almost confined to the region below or between the tide-marks. Only small numbers have been caught in shallow water, between the life-boat slip and the breakwater. Large numbers of young forms as well as ovigerous females have been obtained by wading along the water's edge at night both at high and low water.

Seasonal abundance *Siriella jaltensis* seems to be a migratory species. The first migrants in the first week of July appear to include both immature and mature individuals of both sexes. The occurrence of this species in the later months, from September to December, is almost entirely in accord with its diurnal movement when the number obtained in the daytime is not comparable to the large number that occurs after dark. Fage (1933) has recorded catches 2,000 m. and 1,250 m. away from the shore at a depth of 60-70 m. It is thus assumed that this species moved in and out of the Bay regularly in accordance with the change of night and day during the winter months. In seasonal frequency a rapid rise is shown reaching its maximum in September, then it decreases ~~slightly~~ in October and once again increases in November and December (Fig. 10). This species becomes extremely rare in the months from March to May of 1950 when its occurrence is only marked by the appearance of occasional males in the surface tow-net at night, and a few non-breeding individuals on the bottom in the daytime. The observation does not seem to agree

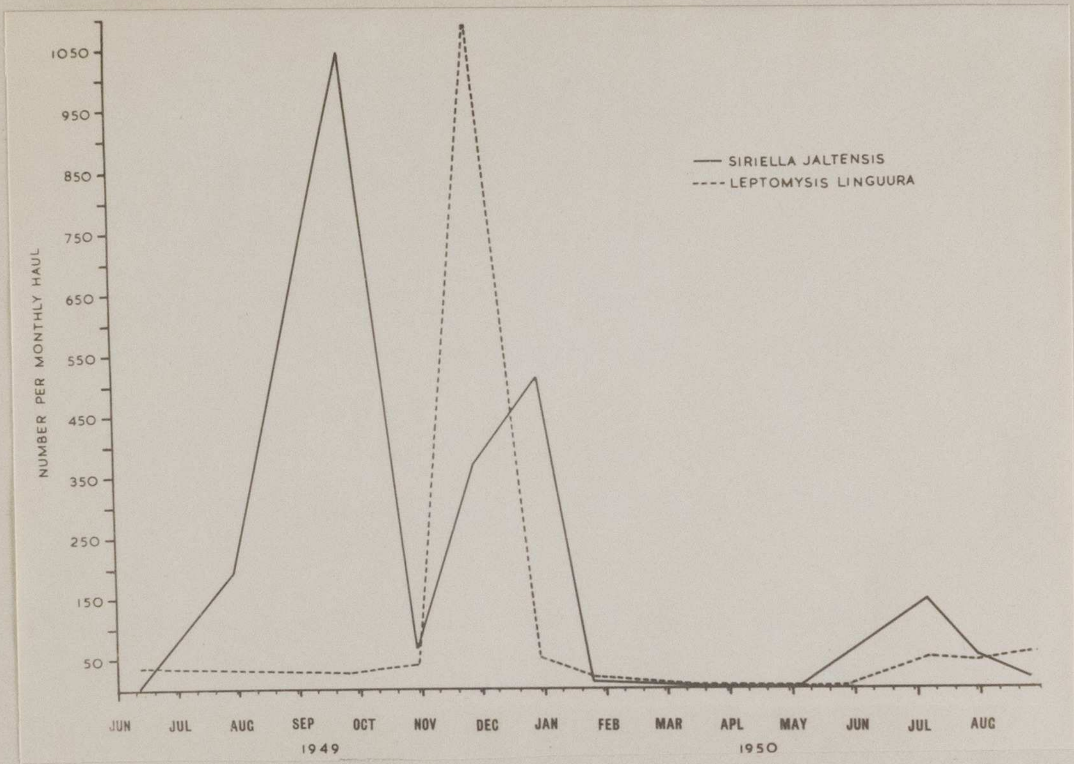


Fig. 10. Siriella jaltensis and Leptomysis linguura.
Total number per monthly haul throughout the period
June 1949 to August 1950.

completely with Fage's result (1933) at Concarneau, that: "Il y est rare jusqu'à la fin de février, devient très abondant en mars, puis se raréfie de nouveau; un autre maximum se trouve placé en août-septembre, après quoi nos pêches se font encore pauvres jusqu'à l'approche du printemps suivant. Nous avons donc là aussi deux maxima, l'un en mars, l'autre en août-septembre."

Reproduction Ovigerous females have been obtained from the beginning of July to the end of November. The bulk was collected from July to September. This does not agree with the Plymouth record of June (Tattersall 1938).

The first comparatively young specimens, measuring 7 mm., appeared in Port Erin Bay on July 7th, 1950, and another sample of 62 individuals of similar size was obtained at Fleshwick on June 21st, 1949. The autumn and winter maxima consist almost entirely of young forms, belonging to one size group, 5 - 9 mm.

Diurnal movement   Siriella jaltensis, as shown in Table 11, performs conspicuous diurnal movements.

Table 11   Siriella jaltensis   Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day.
H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	0 (L.W.)	11 (H.W.)	530 (L.W.)	264 (H.W.)
30 Oct.	15 (H.W.)	0 (L.W.)	22 (H.W.)	27 (L.W.)
24-25 Nov.	6 (L.W.)	6 (H.W.)	295 (L.W.)	60 (H.W.)
1950				
4 May	0 (L.W.)	0 (H.W.)	0 (L.W.)	1 (H.W.)
31 May	0 (L.W.)	0 (H.W.)	4 (L.W.)	0 (H.W.)
7 July	17 (H.W.)	63 (L.W.)	66 (H.W.)	0 (L.W.)
28 July	18 (L.W.)	6 (H.W.)	10 (L.W.)	21 (H.W.)
21 Aug.	0 (H.W.)	0 (L.W.)	2 (H.W.)	0 (L.W.)

In the months of September, October and November, few of this species appear in the Bay in the daytime, but large numbers are recorded at night. It is necessary to emphasize the point that most of the night catches have been obtained by means of wading along the water's edge. A number of 784 out of a total number of 794 specimens in the night hauls on September 26th, 1949, and 206 out of 355 specimens on November 24th, 1949, were obtained by wading. In the summer months, except on July 28th, 1950, when a number of ovigerous females were caught on the bottom along the Raglan Pier at night, all the samples show that this species, though present on the bottom layer in the daytime, is apparently absent from it after dark. Samples also show that this species is common on the surface at all regions at night. The numbers caught in the surface tow-net in the summer months are equivalent to and sometimes even exceed the day catches from the bottom.

Ovigerous females, mature males and young forms, are all present in the surface population. Siriella jaltensis provides, therefore, two types of movement: (1) the diurnal and vertical movement from the bottom, where it remains in the daytime, to the surface at night, and, (2) the seasonal movement presumably from the offshore to the inshore water in a nocturnal excursion in the later part of the year. The latter movement shows more horizontal than vertical aspects. This is shown by the aggregation of large numbers along the water edge after dark in the winter months.

Schistomysis spiritus Norman

This species is extremely abundant throughout the year in Port Erin Bay, and is highly gregarious. The population, as a whole, is confined close to the low water area and moves back and forth with the ebbing and flowing tides. It is rarely obtained in the region between the life-boat slip and the breakwater, except for the small numbers that have often been caught in the surface tow-net at night. This species can easily be observed along the water's edge of the low tide on a calm evening while enormous numbers associate in large shoals, swimming gently a few inches above the bottom and foraging after the food particles which are constantly churned up by the breaking waves.

From the table (Appendix), it is clear that this species aggregates in large numbers along the water's edge in the early morning (26.IX.49, 8:35 - 8:45 a.m.; 25.XI.49, 9:03 - 9:15 a.m.; 4.V.50, 6:20 - 6:30 a.m.; 31.V.50, 6:15 - 6:25 a.m.; 7.VII.50, 4:10 - 4:20 a.m.; 21.VIII.50, 6:15 - 6:25 a.m.) and evening (30.X.49, 3:40 - 3:50 p.m.; 24.I.50, 4:30 - 4:40 p.m.; 14.III.50, 3:15 - 3:25 p.m.; 4.V.50, 6:20 - 6:30 p.m.; 31.V.50, 6:10 - 6:20 p.m.; 7.VII.50, 7:05 - 7:15 p.m.; 28.vii.50, 4:50 - 5:00 p.m.; 21.VIII.50, 4:20 - 4.30 p.m.) and again after dark (26.IX.49, 2:20 - 2:30 a.m.; 30.X.49, 8:50 - 9:00 p.m.; 24.XI.49, 9:00 - 9:10 p.m.; 31.I.50, 6:10 - 6:20 p.m.; 21.III.50, 7:50 - 8:05 p.m.; 31.V.50, 1:50 - 2:00 a.m.; 8.VII.50, 11:20 - 11:35 p.m.) and show intense swarming both at dawn (26.VII.49, 5:30 - 5:40 a.m.; 21.I.50, 7:30 - 7.40 a.m.) and at dusk (17.I.50, 4:50 - 5.00 p.m.; 21.VII.50, 9:30 - 9:45 p.m.)along low water mark. Aggregation along the water's edge is an effect of an extensive horizontal movement which occurs during most part of the day and to a certain extent at night. The aggregation does not represent the whole population. The number, especially of the mature forms at the adjacent area is significant. As shown in the samples, a considerable number of mature forms appear along Raglan Pier at low water and along the mid-tide level at high water. Swarming is found to be an effect of two combined factors: its instinctive response to the faint light both of dawn and dusk, and the tendency of the ebbing tide to concentrate the population from intertidal area to low water's edge. Samples of swarming show that the whole population concentrates close to low water's edge. The number obtained simultaneously in the adjacent area is insignificant, as is shown by the small numbers obtained along the Raglan Pier, which is only 33 m. from the low water neap tidal mark.

Correlation of the aggregation period with light intensity by photometric measurement is not covered in the present study. Attempts have been made however to trace out the range of movement and the length of the period according to the time of sunset and sunrise. The present material shows that the aggregation in the months from November to March seems to differ from that of the remainder of the year; during these months, the aggregation is reduced both in duration of time and in range of movement. The reduction of range is shown by the absence of this species along high water's edge both in the daytime and at night in November (24.XI.49, 2:30 - 2:40 p.m.; 11:13 - 11:25 p.m.). The phenomenon is more marked in the months from December to March, when this species is absent from the water's edge both at high and low tide at the period from the latter part of the morning to the earlier part of the afternoon (30.XII.49, 2:30 - 2:40 p.m.; 12.I.50, 11:25 - 11:40 a.m.; 30.I.50, 2:30 - 2:40 p.m.; 21.II.50, 9:55 - 10:10 a.m.;

29.III.50, 9:25 - 9:35 a.m.). Other samples show this species occurs along low water's edge at 3:15 p.m. (14.III.50) and along high water's edge at 9:27 a.m., 4:30 p.m. respectively (24.I.50). It seems to suggest that during these months there is an interrupted period in aggregation along the water's edge roughly from 10:00 a.m. - 2:30 p.m. The aggregation period seems to be lengthened in the summer months. Though most of the samples from May to August were collected in the four typical periods around 6:00 a.m., 1:00 p.m., 6:00 p.m. and 1:00 a.m., the results agree that at times of high water the population is dispersed between the mid-tide and the low-tide level with the ovigerous forms predominant along the latter region and few along high water's edge, and at times of low water the population consists almost entirely of young forms that occur along low water's edge.

Aggregation seems to vary with different size groups. Samples taken on 31.V.50, 7.VII.50, 28.VII.50, and 21.VIII.50, were treated as if these samples had been taken on one day at four tides: 6:00 a.m., 12:00 noon, 6:00 p.m. and 12:00 midnight, starting with low water. Large numbers of all size groups aggregate along low water's edge in the early morning, with a small number remaining at Raglan Pier. Few young forms occur along high water's edge at noon time, while nearly the whole population disperses between the mid-tide level and the low water mark, with both ovigerous females and mature forms dominating at the latter locality. The aggregation at low water in the evening is marked with the same features as that of the early morning. Different features are noted at high water at midnight when large numbers of ovigerous females and mature forms aggregate along the water's edge, and when there is a sharp decrease in the number of young forms.

In the case of high water in the early morning, young forms dominate at the water's edge while ovigerous females and mature forms are either dispersed at different regions within the tide-marks or show high numbers along the mid-tide level. In the evening, the same features are noted, save that the number of the ovigerous females and the mature forms in some cases are found to be high along Raglan Pier. When it is low water at midnight the population becomes very small.

From these observations it is apparent that the young forms are more tide-bound than the mature forms, especially in the early morning and in the evening, and that the mature forms in the daytime are confined in the region between the low water level and the mid-tide level, and become active with the approach of dark.

A series of samples by wading along the water's edge at 1½ hour intervals between the low water and the high water were collected on 29.IV.50, and the results were shown in Table 12.

Table 12. Total number of Schistomysis spiritus caught along the water's edge by wading at different states of the tide at different periods of the day.

Time of sampling (hrs.)	Locality	Condition of Light	Ovigerous Females	SIZE RANGE (IN MM.) TOTAL NUMBER PER HAUL 13-15	10-12	7-9	4-6	3	Weight (gm.)
1450-1505	Low water	Bright					4528	1580	3.2
1950-2005	about mid-	Dusk	276		128	208	5152	1900	7.3
2030-2045	tide	Dusk	293	75	96	210	1824	944	7.9
2113-2125	High water	Dark	850	66	1221	2881	8976	1782	36.2

The occurrence of large numbers of young forms along the water's edge in the afternoon and the sudden increase of the ovigerous females and mature forms at dusk, confirm the suggestion over the tide-bound instinct of the young forms, especially during the daytime, and the tendency of the adults to move towards the water's edge at the approach of dark.

It is also noticed that cloudy or stormy weather seems to increase the numbers along the water's edge in the daytime (21.VIII.50, 11:10-11:20 a.m.). Abundance of the population seems to bear no relationship to the lunar periodity.

To sum up, the horizontal movement of this species is strongly influenced by its gregarious instinct and by its response to the light intensity, to the tidal movement in the intertidal area, and to other physical factors. The density of population in different zones in this area is partly effected by the horizontal movement and partly correlated with biological factors such as the tide-bound instinct of the young forms and the negative geotaxis of the mature forms.

Schistomysis spiritus performs vertical movements after dark, moving toward and scattering widely at the surface. It is shown in the small numbers obtained along the bottom after dark (Table 13) and by the occurrence at the same time of specimens in the surface tow-net over a wide area which includes the surface over the life-boat slip and inside the breakwater.

Table 13. Schistomysis spiritus.

Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day.

H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	105570 (L.W.)	6468 (H.W.)	141 (L.W.)	4308 (H.W.)
30 Oct.	7632 (H.W.)	23313 (L.W.)	199 (H.W.)	62 (L.W.)
24-25 Nov.	27482 (L.W.)	6192 (H.W.)	185 (L.W.)	65 (H.W.)
1950				
4 May	10743 (L.W.)	443 (H.W.)	2782 (L.W.)	214 (H.W.)
31 May	935 (L.W.)	347 (H.W.)	274 (L.W.)	2064 (H.W.)
7 July	8068 (H.W.)	1810 (L.W.)	7649 (H.W.)	no sample
28 July	63015 (L.W.)	2490 (H.W.)	46186 (L.W.)	2489 (H.W.)
21 Aug.	26058 (H.W.)	83276 (L.W.)	14527 (H.W.)	154 (L.W.)

However, the number in the surface tow-net at night is not at all comparable with that obtained along the bottom during the day. It is probable that, due to the wide distribution at the surface, the number at a certain area is decreased. Besides, the disturbance caused by the motor-boat propeller might to a certain extent account for the presence of the small number in the net. The main shoal keeps to the surface along Raglan Pier at low water, moves to the intertidal region, and gathers at the edge of high water in great numbers.

As has already been mentioned, it is evident that the movement of Schistomysis spiritus is a part of their daily activity. During the horizontal movement, it is gregarious and moves close to the bottom within the intertidal area in accordance with the tidal movement. When the condition of the light and tide reach the optimum, it swarms. During the vertical movement, it moves upward to the surface after dark, scatters over a wider area than the intertidal region, and also becomes aggregated along the water's edge at high water.

Seasonal abundance A most striking fact in the observation of Schistomysis spiritus is their abundance throughout the year. The seasonal abundance of the species is difficult to estimate due to the difference of the time when the monthly samples were collected. The number varies greatly because of the different factors such as the light intensity, the weather, etc., as mentioned above. If the effect of these factors could be ignored, the number appears to reach its maximum in August. As has already been mentioned, poor weather conditions tend to increase the number of S. spiritus along the water's edge. This may be applied to the sample collected on 22.VIII.50, a day of dull and breezy weather that seems to have stimulated the unusual swarming at low water around noon-time (11:10 - 11:24 a.m.). If such a case be considered and the additional number be discounted, the maximum appears to fall around the end of July. The present material shows that this species is least abundant in March and at the end of May (8253, 3602) and fairly abundant (31206, 33926, 15828, 14182) in October, November, January and the beginning of April, and very abundant (131318, 114180, 124015, 105570) in July, August, and September. The population is composed mainly of young forms in the months of greatest abundance.

Reproduction The breeding period of S. spiritus lasts from January to the early weeks of December. The ovigerous females are abundant throughout most parts of the season, except at the end of June, in the early part of July and at the end of August in the year 1950, when the egg-carrying females become rare. The bulk was taken at the end of July.

The fecundity of the ovigerous females of Schistomysis spiritus is related to their body length collected on the same date. In Table 8 it is seen that the average number of eggs or embryos increase with the body length of the ovigerous females. Nevertheless on the whole, the fecundity seems to be more closely related to the change of season. Fig. 11 shows a gradual increase both in body length and in the number of eggs or embryos in the brood pouch from January to May, and then a decrease in both till the body length reaches its minimum in September and the number of eggs or embryos reaches its minimum in December. The increase in size and in fecundity from January to February, as shown in the histogram, is comparatively slight. The change in March is rather abrupt; both the body length and the number of eggs or embryos increase suddenly till these reach a maximum in May. The condition in May differs from that of April in the existence of at least two groups of breeders which presumably correspond to the winter and the summer stocks of Praunus flexuosus. It appears that the group that corresponds to the winter stock has reached its maximum both in body length (15 mm.) and in the contents of the brood pouch, while the other group, the summer stock (12 mm.) first indicates its appearance. In June there is a sharp decrease of the former as well as an increase of the latter. The ovigerous females become comparatively rare in this period, till the early part of July. The quiescent period suggests probably the existence of a gap in breeding which is possibly a result of the dying out of the winter stock when the summer stock has not yet increased in quantity. The modal size group of the ovigerous females decrease from 13 & 14 mm. in July

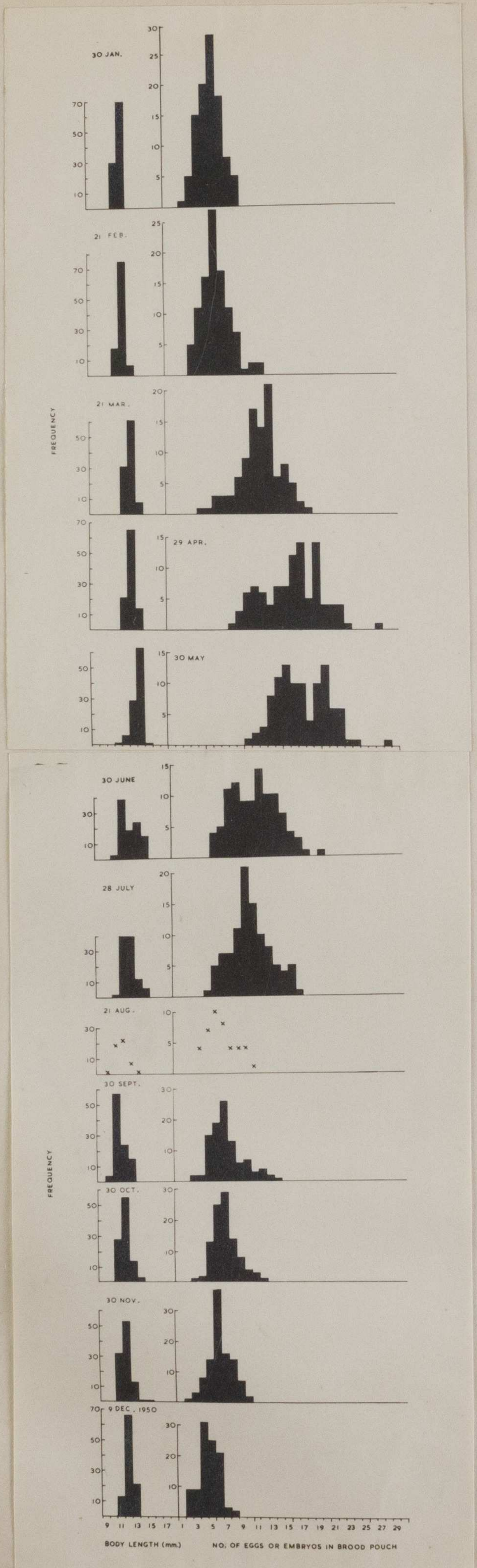


Fig. 11.

<u>Schistomysis spiritus</u>

Diagram showing the size composition of ovigerous females and number of eggs or embryos in the brood-pouch throughout the year, 1950.

X, number frequency - samples with less than 100 individuals.

Block, percentage frequency- samples with 100 individuals.

to 11 mm. in September, and increase slightly from October to December (12 mm.). The number of eggs or embryos after reaching its maximum range in May, begins to decrease; in July it shows a similar range to that of March and in September and October the range is similar to that of February and January.

As shown in Table 8, the potentialities of the ovigerous females of the same body length differ greatly with the season. Females of 12 and 13 mm. produce respectively average number of 13.5 and 16.4 eggs or embryos in May, and the corresponding sizes in December produce average number of 4.4 and 5.3 eggs or embryos respectively.

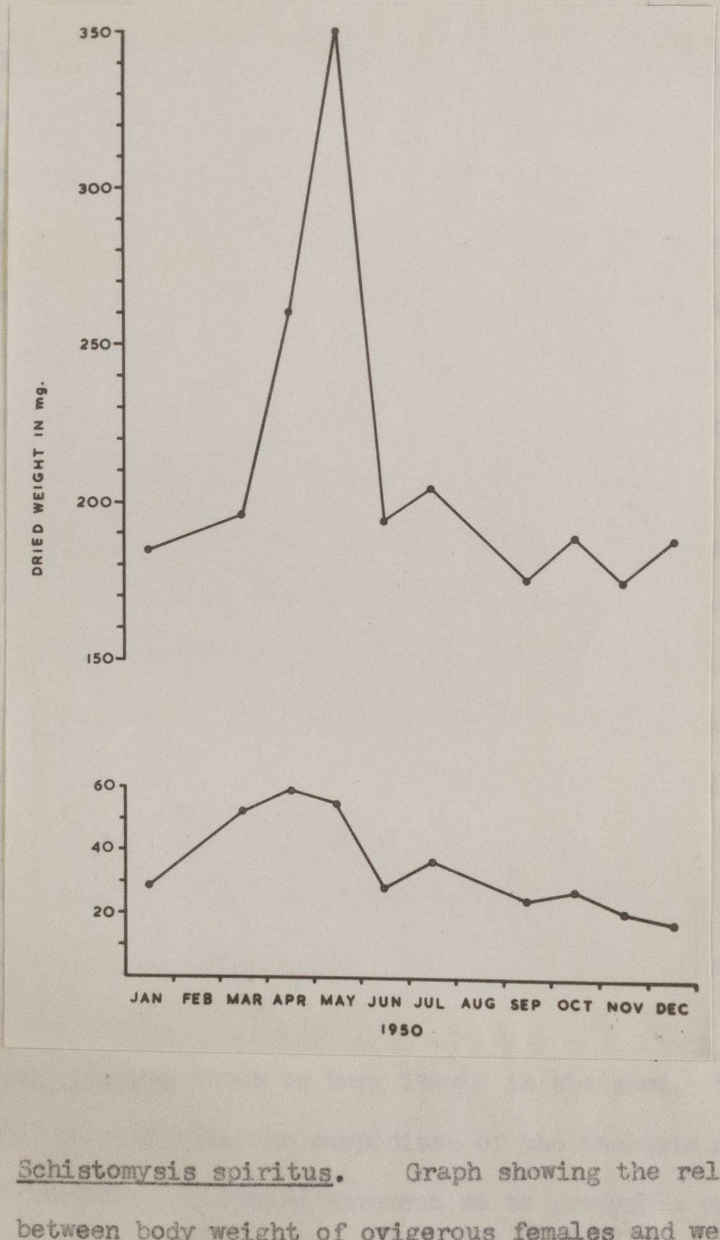


Fig. 12. Schistomysis spiritus. Graph showing the relation between body weight of ovigerous females and weight of eggs or embryos in the brood-pouch throughout the year. ● Body weight; ⊙ Weight of eggs or embryos.

Through comparison of Figs. 11 and 12, it will be seen that the change of the body weight agrees with the change of the body length; both reach the maximum in May. The change of weight of the brood-pouch content, as shown in Fig. 12. coincides generally with the body weight, except that the weight of the brood pouch content reaches its maximum in April. The change of the body weight and of the weight of the brood pouch content, though not comparable in December, coincides respectively with the change of the body length and of the number of eggs or embryos in the brood pouch.

Paramysis arenosa (G. O. Sars)

General distribution and behaviour This species is abundant at low water mark and has occasionally been found in the shallow water along the life-boat slip and inside the breakwater, especially in the winter months. It moves to the intertidal zone both in the day-time and after dark, but none has been caught at high water mark. In the months of May, June, July, August and September, individuals of all size groups, especially ovigerous females, are abundant along the water's edge at low water, but this does not occur in the rest of the year. This species is a bottom-living form and rests on the substratum in the daytime. When kept in the tank, it is often observed waving the exopodites of the thoracic appendages at intervals; the movement, though very rapid, is of short duration, and after a few strokes there is a comparatively long rest when the action is once again resumed. The function of this type of movement is not understood; it is probably part of the feeding activity to gather the food particles from the surroundings or maybe simply an action to cause a stream of water to circulate through the respiratory groove.

Paramysis arenosa tends to bury itself in the sand. This is achieved by shuffling the sand with the exopodites of the thoracic appendages by a strong backward and upward movement so to produce a strong current which throws the sand backwards and in the meanwhile it moves forward and rests in the hollow produced by the shuffling.

The production of the food current by means of the rotating movement of the exopodite of the thoracic legs, as described by Cannon and Manton (1927) in their work on the feeding habits of Hemimysis lamornae, does not occur in P. arenosa. This species is also observed ploughing sometimes through the sand with the antennal scales, with the body tilted to a certain inclination. In this respect, it is very similar to Hemimysis lamornae.

Seasonal abundance P. arenosa becomes very rare in December when the only individuals are small numbers of ovigerous females and mature forms. The number of adults and immature forms, 6-7 mm., increases markedly in January; the latter group seems to have been hatched in the previous year. These individuals are apparently responsible for the increase of the breeders in the following months. The number of young forms shows marked increase in the beginning of July, and the population as a whole reaches its maximum at the end of that month (Fig. 3). In contrast to other species at their maximum abundance, the ovigerous females of P. arenosa are about twice as numerous as the young forms. The population shows a general decrease of all size groups at the end of August and September. There is a slight increase of young forms, 4-5 mm., in October, as well as the immature forms, 6-7 and 8-9 mm., in November.

Reproduction The ovigerous females occur at all months throughout the year. The number increases in May and remains abundant till the end of September.

The modal group of the ovigerous females (Fig. 13) undergoes several changes from 10 mm. in March to 9 mm. at the end of July, but the number of eggs or embryos in the brood-pouch shows slight change. Both the body length and the fecundity of the ovigerous females decrease markedly in August.

Diurnal movement This species does not show consistent difference in number between daytime and dark. As shown in Table 14, the samples of 24, 25.XI.49 show the number slightly higher after dark, but the maximum numbers in the samples of 26.IX.49, 7.VII.50, 28.VII.50

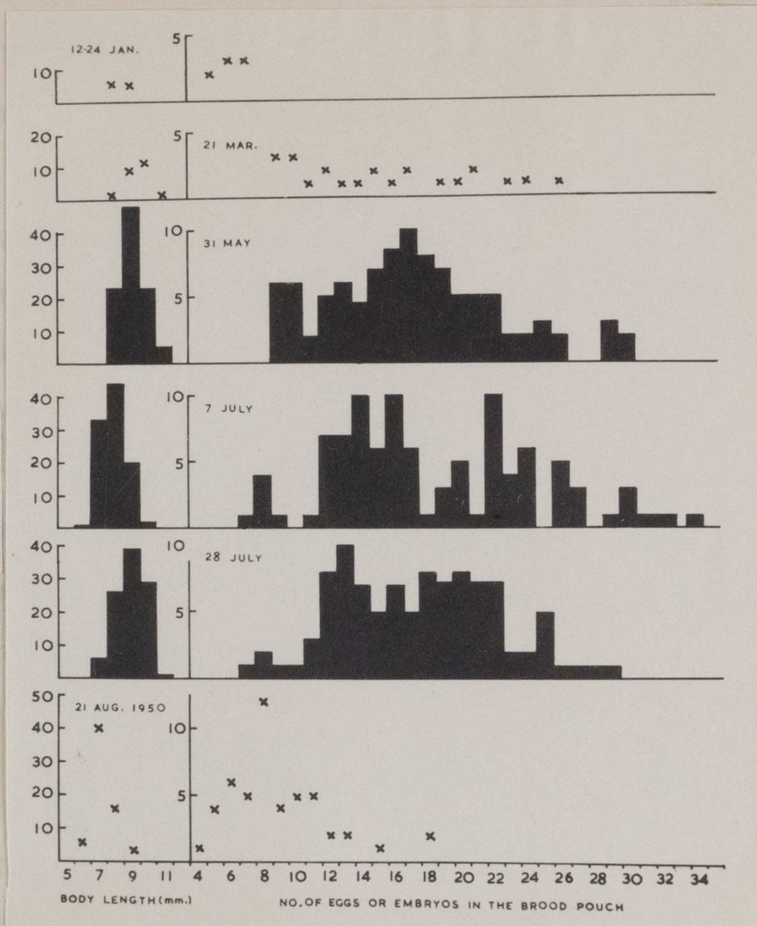


Fig. 13. Paramysis arenosa. Diagram showing the size composition of the ovigerous females and number of eggs or embryos in the brood-pouch throughout the months of the breeding period. X, number frequency - samples with less than 100 individuals. Block, percentage frequency - samples with 100 individuals.

Table 14. Paramysis arenosa. Summary of Data, showing the number of individuals obtained at different states of the tide at different periods of the day. H.W. High water; L.W. Low water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	192 (L.W.)	10 (H.W.)	19 (L.W.)	26 (H.W.)
30 Oct.	77 (H.W.)	47 (L.W.)	71 (H.W.)	14 (L.W.)
24-25 Nov.	6 (L.W.)	42 (H.W.)	50 (L.W.)	87 (H.W.)
1950				
4 May	56 (L.W.)	0 (H.W.)	124 (L.W.)	15 (H.W.)
31 May	131 (L.W.)	22 (H.W.)	1 (L.W.)	30 (H.W.)
7 July	45 (H.W.)	616 (L.W.)	12 (H.W.)	- (L.W.)
28 July	665 (L.W.)	357 (H.W.)	1836 (L.W.)	205 (H.W.)
21 Aug.	176 (H.W.)	300 (L.W.)	152 (H.W.)	300 (L.W.)

and 21.VIII.50, were obtained at certain periods in the daytime and invariably in low water. It is likely that the number in the samples is strongly influenced by the concentrating effect of low tides,as the same effect has been shown on Crangon vulgaris.

A few individuals have been obtained in the surface tow-net after dark in August. Observations in the laboratory show that some individuals swim actively in the surface layer of water after dark. Foxon (1940) investigated the reaction of Hemimysis lamornae to the stimulation of light and gravity, and observed that mysids swim actively on the surface under red light in a dark room, but sink immediately to the bottom when the light is switched on.

Leptomysis linguura (G. O. Sars)

General distribution This species is faily common throughout the later part of the year. It is noted that this species tends to keep to shallow water in July and August, and moves to the region between the low water and the mid-tide level from September to May, but none has been obtained along the high water mark.

Seasonal abundance The occurrence of Leptomysis linguura in the Bay is marked by the abundance of adults of both sexes and the scarcity of young forms, throughout the greater part of the year. In the months of January, July and August, the numbers of ovigerous females obtained are no less than half of the total specimens. Young forms show a sudden increase in number in November, and the population as a whole reaches its maximum at the end of that month (Fig. 10). Young forms were obtained throughout December. This species becomes very rare from February to May.

Tattersall (1938) records that the breeding period of Leptomysis gracilis extends from June to October at Plymouth, and that the summer maximum of frequency from June to August, as shown in his graph, is composed of adults of both sexes and immature forms. The bulk of his adults, as shown in his table, was collected from July to August, a period which coincides with that when most of the ovigerous females of Leptomysis linguura were obtained in Port Erin Bay. It is also noted that the breeding activity of both L. gracilis at Plymouth and L. linguura at Port Erin Bay, slackens off in September and October, though that of L. linguura lasts till November. However, it is questionable whether this slightly longer breeding period would be the determining factor of the summer maximum of L. gracilis and the winter maximum of L. linguura. Apart from the difference in the inshore and offshore nature of L. linguura and L. gracilis, it is more likely that the aggregation of L. linguura close to the water's edge in the latter months might account partly for the sudden increase in number in the November catches.

Diurnal movement Russell (1925, 1928, 1931, 1933) shows that Leptomysis gracilis is a bottom dweller in the daytime, moves upward from the bottom with the approach of darkness, and can then be obtained in large numbers in the mid-water. From Table 15, it is clear that the number of L. linguura on the bottom during the daytime is higher than that at night.

Table 15. Leptomysis linguura.

Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day. H.W. High Water; L.W. Low Water.

DATE	Morning	Daylight	Evening	Midnight
	Number of Individuals per Period of the Day			
1949				
25-26 Sept.	72 (L.W.)	4 (H.W.)	0 (L.W.)	17 (H.W.)
30 Oct.	6 (H.W.)	19 (L.W.)	14 (H.W.)	1 (L.W.)
24-25 Nov.	821 (L.W.)	153 (H.W.)	96 (L.W.)	13 (H.W.)
1950				
4 May	1 (L.W.)	0 (H.W.)	1 (L.W.)	0 (H.W.)
31 May	1 (L.W.)	0 (H.W.)	2 (L.W.)	0 (H.W.)
7 July	15 (H.W.)	15 (L.W.)	15 (H.W.)	6 (L.W.)
28 July	17 (L.W.)	3 (H.W.)	14 (L.W.)	11 (H.W.)
21 Aug.	21 (H.W.)	10 (L.W.)	21 (H.W.)	4 (L.W.)

In September, October and November, large numbers of this species have been obtained along the water's edge in the daytime, but few at night. The results are similar, to a certain extent, to those for L. gracilis, in that the number decreases on the bottom after dark. Whether it moves upward or not cannot be decided since the present work does not include samples from all depths.

The graph also shows that in the samples of 4.V.50, 31.V.50, 28.VII.50, and 21.VIII.50, there is a general tendency to decrease in number on the bottom in the morning, to rise in the evening and to decrease again after dark. The reason for these irregularities in number is not understood. Probably the small number in these samples cannot be taken as representative of the species as a whole.

Leptomysis linguura, therefore, performs two types of movements:

(1) diurnal and presumably vertical movement when it is supposed to move from the bottom to some level below the surface;

(2) seasonal movement when it moves from the shallow water to the adjacent area of the intertidal region in the period from September to May.

Leptomysis mediterranea G. O. Sars

This species occurs in small numbers in Port Erin Bay. The specimens are found to be exclusively ovigerous females in February, March, July, and August, ovigerous females accompanied by young forms in September and October, and only young forms in November. Ovigerous females occur in all regions below low water mark and many have been obtained by wading along the water's edge. The young forms have mostly been obtained along low water mark and up into the intertidal region.

Reproduction Ovigerous females have been obtained in February, March, July, August, September and October, being most abundant in September. Number of eggs in the brood-pouch ranges from 9 to 27.

The first young form, measuring 11 mm., was caught on 21.VIII.5o. The young forms become fairly common throughout the end of November. The highest number appears as a sample of 77 immature forms, ranging from

5 to 11 mm., was obtained by wading along the low water mark at 2:10 - 2:20 p.m. on October 31st, 1949. Out of a total of 121 specimens, 98 were caught during the daytime and 23 by night.

Mysidopsis gibbosa G. O. Sars

This species occurs in very small numbers in the Bay from March to September. All the specimens have been obtained from the bottom between the life-boat slip and the breakwater.

Ovigerous females have been collected in May, July and September. Tattersall (1938) caught one ovigerous female at Plymouth on November 1 and he suggests that, together with the previous Plymouth record, the breeding season extends from April to November (16 out of 21 specimens were caught in the daytime).

Hemimysis lamornae (Couch)

This species appears to be a rare visitor in September and November. All the specimens, except for one caught in the surface tow-net after mid-night, and three in November from the bottom in the morning, have been obtained from the bottom after dark. Of a total of 32 specimens, in September, 2 are juveniles, 6 females carrying eggs, and the remainder are mature individuals.

Gammarus locusta (Linné)

General distribution The habitat of this species appears to change with the drifting of the algal detritus. The population of the months from January to March consists mainly of young forms, measuring 3-5 mm., which are almost entirely collected along the water's edge. Few mature forms have been obtained in these months inside the breakwater and none along the life-boat slip. The scarcity corresponds to the absence of algal fragments in these regions. The young forms at the water's edge decrease considerably in May and become completely absent in June, though the percentage of young forms remains high in the shallow water. The population along the life-boat slip and the breakwater increases considerably with the presence of algal fragments from June till October. A swarming in November and December follows immediately after the algal fragments have drifted to the water's edge. The results do not fully agree with Watkin's (1941) suggestion that the young forms of Gammarus locusta perform more extensive horizontal movement than the adults. It is assumed that the extensiveness of the horizontal movement of the young forms as well as of the adults depends on the environmental factors.

Spooner (1947) and Segerstrale (1947) record that G. locusta can tolerate low salinities down to 5-6‰. In Port Erin it is only found in fully marine conditions (Jones, 1948). In the intertidal area, this species is often observed among the algae in the rock pools at Spaldrick, but along the rocky shore inside the breakwater it is scarce, though Marinogammarus obtusatus is exceedingly abundant under the stones and gravel.

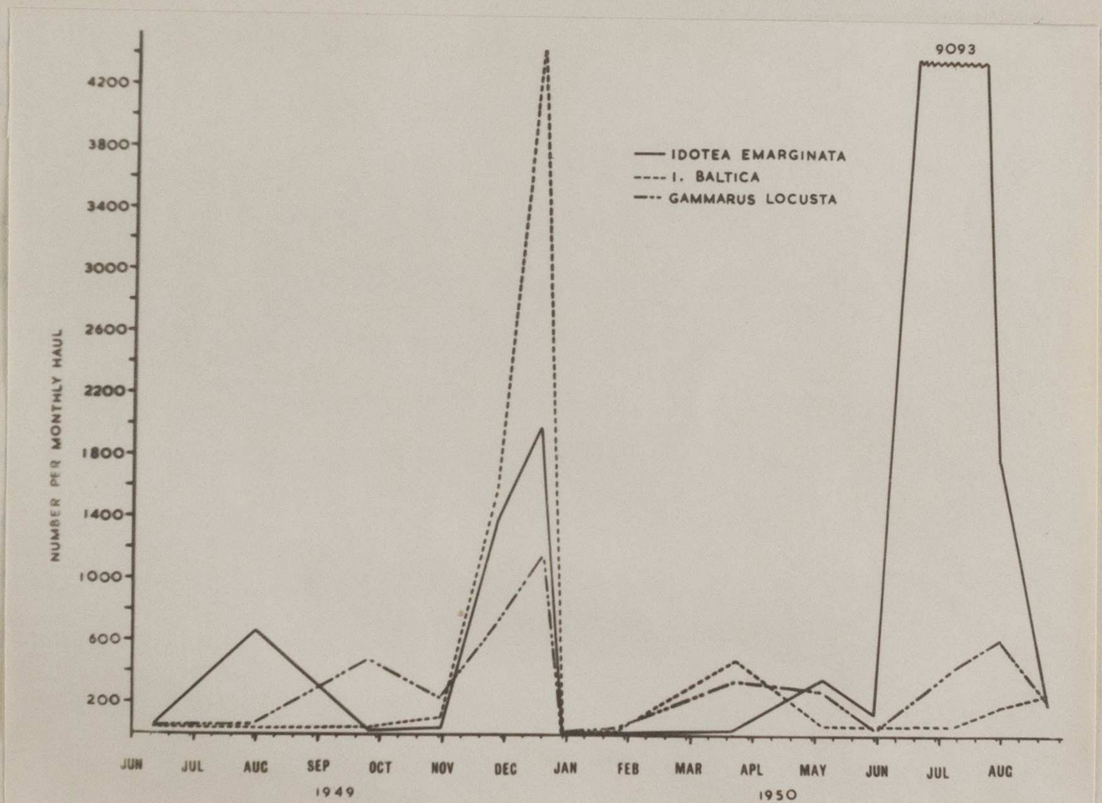


Fig. 14. Gammarus locusta, Idotea emarginata, and I. baltica. Total number per monthly haul throughout the period, June 1949 to August 1950.

Seasonal abundance The seasonal abundance is marked by summer and winter maxima (Fig. 14). The results of the summer maxima for the years 1949 and 1950 do not coincide in date; the peak of 1949, 345, falls in September, whereas that of 1950, 616, falls in July. The peak of 1950 is notably much higher in number. It is also noted that the summer maximum in July of 1950 consists mostly of ovigerous females and mature forms (77.3%) while that in September of 1949 consists mainly of young forms (66.5%). Unfortunately the work was not carried on till September of 1950 and it is thus impossible to prove whether the difference is due to annual variations or to other factors.

The winter maximum is shown in the swarming along the water's edge in November and the early part of December. The population consists of large numbers of ovigerous females and a mixture of all size-groups with a predominant number of young forms. The swarming is supposed to be of the same nature as that of other sublittoral amphipods and isopods which associate among algal detritus. The numbers in the swarming increases during high tides, especially after dark. Minimum numbers are found in January.

Reproduction Ovigerous females have been obtained in all months in the year except in February when no sample was taken. The bulk was obtained in November and December of 1949 and July of 1950, a period corresponding with the seasonal abundance.

Blegvad (1922) states that the breeding period of Gammarus locusta at Nyborg Fjord lasts from February till the first part of October. He further separates the population into the winter and the summer stocks, of which the former breeds in the early part of the season (February-July) and the latter replaces the former in the remainder of the season, and there is a quiescent period from November to January when these gammarids increase considerably in size.

As shown in Table 16, the ovigerous females are smaller in July than those collected in November and December, though both groups share the same modal size group (12 mm.).

Table 16. Gammarus locusta. Size composition of the ovigerous females and number of eggs or embryos in the brood-pouch, in November - December 1949 and July 1950.

Body Length (in mm)	Date: No. of Individuals: 24 Nov. 1949	16.Dec. 1949	7 July 1950	28 July 1950
10	1			2
11	7	7		26
12	20	10	2	28
13	18	6	3	14
14	3	7		10
15	3	4	1	
16				8
17				
18				1

No. of eggs or embryos in brood-pouch	Date: No. of Individuals: 24 Nov. 1949	16 Dec. 1949	7 July 1950	28 July 1950
9-14	1			
15-19	1			1
20-24	7	1		1
25-29	4	2	1	4
30-34	4	2		8
35-39	2	6		7
40-44	7	4		9
45-49	3	2		8
50-54	2	1	1	7
55-59	1			6
60-64	2	2		6
65-69	3			7
70-74	2	2		3
75-79	2		1	7
80-84		2		5
85-89		3		3
90-94				2
95-99	1	1		1
100-104				3
109-119				3
120-130				3
131-140			1	1
141-150				
151-160				
161-170				1
171-178				2

It is noted that there are a few large ovigerous females, measuring 16-18 mm., in the collection of 28.VII.50, though none has been found in the winter months. Blegvad (1922) shows that the ovigerous females of this species are bigger in April and May (10-22 mm.) than those in July and August (6-16 mm.) in Danish waters.

The fecundity shows great variation within the same group; the general tendency is for a positive correlation of fecundity with body length. Sexton (1928) obtained similar results in the reproduction of G. chevreuxi and states that "the number of young in a brood increases as the female grows." Cheng (1942) shows a positive correlation between body weight and fecundity of Marinogammarus obstusatus and M. marinus, but in the case of G. duebeni, "the fecundity appears to fall after reaching its maximum at the 19 mg. body weight class".

The fecundity of G. locusta shows close correlation with the season, being higher in July than in November and December. In July, even when the few large females of 16 and 18 mm. are excluded, 55.8% of the ovigerous females carry 50-100 eggs, whereas in November and December 67.1% carry 10-50 eggs. The results are similar to Cheng's work (1942) on M. obstusatus, M. marinus and G. duebeni, where it was found that the fecundity is higher in spring than in the winter months.

Diurnal movement   Gammarus locusta performs both horizontal and vertical movements. The horizontal movement varies greatly in extent in winter and summer months. In November and December the horizontal movement becomes extensive and it appears in the swarming along the water's edge. The number increases at high water, especially after dark. (Table 17). In the summer months from May to July, the movement range shows gradual reduction from the intertidal to the shallow water region. In early May the movement extends from the shallow water to the intertidal region. It is shown by the increased population as a whole in the shallow water both in early morning and after dark, and the increase of young forms in the intertidal region in the daytime. There is not much change towards the end of May, save for the general decrease in number.

Table 17: Gammarus locusta

Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day. H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	109 (L.W.)	56 (H.W.)	29 (L.W.)	151 (H.W.)
30 Oct.	2 (H.W.)	3 (L.W.)	85 (H.W.)	150 (L.W.)
24-25 Nov.	14 (L.W.)	96 (H.W.)	173 (L.W.)	427 (H.W.)
1950				
4 May	109 (L.W.)	54 (H.W.)	28 (L.W.)	85 (H.W.)
31 May	8 (L.W.)	28 (H.W.)	6 (L.W.)	7 (H.W.)
7 July	336 (H.W.)	9 (L.W.)	5 (H.W.)	74 (L.W.)
28 July	384 (L.W.)	94 (H.W.)	26 (L.W.)	112 (H.W.)
21 Aug.	63 (H.W.)	87 (L.W.)	50 (H.W.)	31 (L.W.)

The irregularity in May seems to be a natural effect of a transitional period between the extremities of winter and summer. The change is more clearly shown in July when the movement is mostly confined to the shallow water between the life-boat slip and the breakwater, and shows the extension to Raglan Pier as being irregular. The change in this month, therefore, is mainly local. Both samples of July, 7.VII.50 and 28.VII.50, show a distinct increase in number both along the life-boat slip and the breakwater in the early morning and after dark. In the first sample there is an increase along the Raglan Pier in the early morning and after dark, and in the latter the increase is in the afternoon and after dark. It is noteworthy that none of the young forms occur along the water's edge nor in the intertidal area, though in the early part of July the number of the young forms remains high. It is supposed that this change is due to the fact that this species burrows into the deeper layer of algal fragments in the day-time and moves to the upper layer after dark.

The condition in August, September and October seems to repeat the movements in the summer months. The movement extends to the intertidal region and the water's edge in August and September, and is localised in October.

The vertical movement appears only in the small numbers of young forms and mature males caught in the surface tow-net after dark in July, August and September.

Dexamine spinosa (Montagu)

General distribution This species normally inhabits rocks and algae in shallow water and between tide-marks. In this survey it occurred only between the life-boat slip and the breakwater in the months from May to November. This occurrence is associated closely with the presence of the algal fragments in those months; as the algal fragments disappear in the winter months, this species is completely absent from the region along the life-boat slip. None was obtained in December. Three specimens were obtained inside the breakwater, one between the intertidal region and one caught by wading along the mid-tide level in January. It is presumed that this species remains in the sublittoral and littoral zones in winter.

Seasonal abundance The numbers show a maximum in September and a minimum in December (Fig. 7). The population of the maximum period consists largely of young forms, 4-5 mm. and 6-8 mm. (88.3%). There is a marked decrease of the former and an increase of the latter in October and then there is a general fall of both groups in November. The population remains small in the early half of the year, until the number increases suddenly in July.

Reproduction Ovigerous females were obtained in March, May, June, July, August and September. The bulk was obtained in July. The first young forms were obtained in the end of May.

Diurnal movement This species performs both horizontal and vertical movement to a certain degree. The population is mostly confined to shallow water and tends to concentrate along the life-boat slip after dark. The number is consistently higher after dark than in the daytime throughout the year. (Table 18).

Table 18. Dexamine spinosa.

Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day. H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	247 (L.W.)	61 (H.W.)	153 (L.W.)	199 (H.W.)
30 Oct.	17 (H.W.)	15 (L.W.)	189 (H.W.)	258 (L.W.)
24-25 Nov.	6 (L.W.)	5 (H.W.)	17 (L.W.)	27 (H.W.)
1950				
4 May	0 (L.W.)	0 (H.W.)	0 (L.W.)	4 (H.W.)
31 May	4 (L.W.)	1 (H.W.)	4 (L.W.)	8 (H.W.)
7 July	40 (H.W.)	17 (L.W.)	14 (H.W.)	201 (L.W.)
28 July	38 (L.W.)	57 (H.W.)	14 (L.W.)	86 (H.W.)
21 Aug.	67 (H.W.)	27 (L.W.)	30 (H.W.)	93 (L.W.)

The difference in number between the daytime and at night is believed to be, as in the case of G. locusta, a result of localised change. In the laboratory, this species tends to burrow into the algal fragments in the daytime. Perhaps D. spinosa does the same under natural conditions, hiding itself among the algal fragments in the daytime and moving to the surface layer after dark. The horizontal movement is shown by the presence of small numbers, especially young forms, in the region adjacent to the tidal range.

Specimens have not been obtained in the intertidal region until the winter months. One was caught along the water's edge at mid-tide level after dark on 30.I.50, and nine young forms were obtained along the mid-tide level in the morning on 31.X.49.

The vertical movement is shown by the occurrence of young forms (3, 4-5, 6-8 mm.) in the surface tow-net after dark in July, August and September. The size 4-5 mm. is the predominant group in all cases.

<u>Nototropis swammerdami</u> (Milne-Edwards)

<u>General occurrence</u> This species is mainly a sublittoral form "among algae on sandy bottom" (Jones, 1948). It is tide bound to a certain extent, being abundant immediately below the low water and extending to the mid-tide level; except in the swarming period in December, it never occurs along the high water mark. The observations agree with Watkin's result (1941) that "it only occurs in abundance in those (samples) taken in the lower third of the neap-tide range and those near the low water".

<u>Seasonal abundance</u> The number fluctuates throughout the year, being abundant in September and in the early week in December of 1949, and again in March, July and August of 1950; of these months, except December, the population contained largely young forms.

<u>Reproduction</u> Ovigerous females are obtained throughout the year; the bulk was obtained in July and December.

<u>Diurnal movement</u> This species performs both horizontal movement in accordance with the tide, and vertical movement in accordance with the diurnal cycles. Table 19 shows the number decreases markedly from the bottom after dark, when it forms an important species in the surface samples. In July and August, the specimens obtained from the surface represented all stages of maturity, but in September and October the samples contained exclusively adult males.

Table 19. Nototropis swammerdami.

Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day. H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949 25-26 Sept.	2567 (L.W.)	431 (H.W.)	51 (L.W.)	83 (H.W.)
30 Oct.	3 (H.W.)	9 (L.W.)	0 (H.W.)	2 (L.W.)
24-25 Nov.	0 (L.W.)	29 (H.W.)	10 (L.W.)	23 (H.W.)
1950				
4 May	10 (L.W.)	13 (H.W.)	12 (L.W.)	68 (H.W.)
31 May	4 (L.W.)	5 (H.W.)	0 (L.W.)	2 (H.W.)
7 July	859 (H.W.)	0 (L.W.)	6 (H.W.)	13 (L.W.)
28 July	251 (L.W.)	445 (H.W.)	7 (L.W.)	17 (H.W.)
21 Aug.	170 (H.W.)	1006 (L.W.)	107 (H.W.)	114 (L.W.)

Bathyporeia spp. This genus is represented by three species, B. guilliamsoniana (Bate), B. pelagica (Bate), and B. elegans (Watkin). Neither of these species was abundant as compared with other amphipods inhabiting the intertidal region. B. guilliamsoniana was obtained mainly at night in March and May from the bottom at mid-tide and low tide levels, and inside the breakwater. Ovigerous females were obtained from the surface samples on 21.VIII.50. B. pelagica was obtained during the period from February to October and most of the specimens were caught along the water's edge at flood tide. B. elegans is rare; few were obtained near the low water's edge on 24.X.49 and in the surface tow-net inside the breakwater on 9.VI.49 and 21.VIII.50. Jones (1948) finds that this species is abundant in fine sand at a depth of 2-15 m. off-shore.

Haustorius arenarius (Slabber) Only one juvenile specimen was caught near the water's edge at high tide after midnight on 25.IX.49.

Urothoë brevicornis Bate and Westwood Occurs occasionally in the wading samples at the mid-tide and low-tide levels, and invariably in the night samples in May and June 1949. One was caught in the surface tow-net on 9.VI.49, near the low water level at 2230 hrs.

Pontocrates spp. This genus is represented by P. arenarius (Bate) and P. norvegicus (Boeck). P. arenarius is fairly abundant in the samples collected between the low water neap and low water spring; few were obtained from mid-tide to high water levels, and several were caught from the bottom along the life-boat slip at midnight on 25.XI.49. P. norvegicus is less abundant in the samples, as compared with P. arenarius. It occurs mainly in the samples taken in the upper half of the intertidal area, and most frequently along the high water level in flood tide. One of the large samples was taken along the life-boat slip on 9.VI.49. Jones (1948) finds this species "extends into rather deeper water than P. arenarius and will burrow in muddy sand, whereas P. arenarius prefers clear sand. ....
Isle of Man: more abundant in shallow water than between tide marks". Both Watkin (1941) and Jones (1948) agree that the distribution of P. norvegicus ranges from mid-tide level downwards. It seems to suggest that the occurrence of this species along the high water mark in the present work is a result of the horizontal movement with the flood tide.

Ovigerous females of both species occur throughout the year. Specimens of both species were obtained in the day-time and at night but are more abundant in the latter occasion.

Apherusa spp. This genus is represented by two species: A. jurnei (Milne-Edwards) and A. bispinosa (Bate). A. jurnei occurs in small numbers just below the tidal mark in the months from May to June. A. bispinosa occurs in all months in the shallow water and was very abundant in August and September of 1949 when the highest number in a single haul consisted of 1170 individuals. The number fell sharply in October and remained small in the winter months. The catches in the summer months of 1950 were low and were not at all comparable with those of the previous year. The number decreased markedly from the bottom after dark, and small numbers have been obtained from the surface at night. Obviously this species performs diurnal vertical movement between day and night.

Other amphipods   Small numbers of other amphipods occurred in samples of the shallow water regions, mainly in the months from June to September. These amphipods may be listed as follows: Nannonyx goësi (Boeck), Socarnes erythrophthalmus Robertson, Hippomedon denticulatus (Bate), Orchomenella nana (Kröyer), Gitana sarsi Boeck, Panoploea minuta (G.O.Sars), Perioculoides longimanus (Bate & Westwood), Monoculodes carinatus Bate, Calliopius crenulatus Chevreux & Fage, Chirocratus sundervalli (Rathke), Megaluropus agilis Hoeck, Melita palmata (Montagu), M. hergensis Reid, M. obtusata (Montagu), Maera othonis (Milne-Edwards), Dexamine thea Boeck, Hayle prevosti (Milne-Edwards), Aora typica Kröyer, Lembos websteri Bate, Amphithoë rubricata (Montagu), Jassa falcata (Montagu), Caprella linearis (L.).

Two species, Metaphoxus fultoni (T. Scott) and Hyperia galba (Montagu) were obtained once from the surface samples after dark.

Eurydice pulchra   Leach

Common between the mid-tide and high water levels, being more abundant in the latter region. Specimens were obtained both in the day-time and at night; large numbers of 960 and 358 individuals were obtained at midnight hauls along the water's edge at high tide on 26.VII.49 and 4.V.50 respectively. Few were obtained in the surface tow-net along the Raglan Pier in September. Samples contained individuals of adults and juveniles, but no ovigerous females. It became rare in the months from December to February. The observation seems to agree with Elmhirst's (1931) work that in winter this species seeks shelter in the shallow water beyond low water spring.

Idotea emarginata (Fabricius)

General occurrence This species is abundant among the Laminaria bed inside the breakwater of the Bay. The abundance of Laminaria digitata which constitutes the diet of this idoteid, and the shelter afforded by the breakwater, seem to be two associated factors that confine this species to this particular site.

Seasonal abundance The numbers show two peaks, June-July and November-December (Fig. 14). The result is similar to Howes' work (1939) on Idotea viridis at New England Creek in Essex, which shows a summer maximum in June-July and a winter maximum in December. Howes believes that the summer maximum is late, and the reason of its being delayed is due to the carnivorous nature of I. viridis and to its food supply of coelenterates and the Byrozoa, especially of Membranipora crustulenta var. fossaria, which is not available until May. His theory on the food supply, however, is not applicable to the winter maximum, as the coelenterates almost die out in October.

It is interesting to note that these two idoteids have different feeding habits and multiply under entirely different environments, and yet reach maximum numbers in similar periods. The supply of Laminaria as a food source for I. emarginata is continuous throughout the year, and there should be no shortage of food unless I. emarginata changes its diet at certain periods. Observations suggest that this reason does not seem to exist and hence the abundance of I. emarginata seems to depend more strongly on other factors rather than on the richness of the food supply. It seems, both from Howes' work (1939) and the present results, that the breeding behaviour of the Idoteid itself is more important than the environmental factors such as food upon the seasonal abundance.

The winter maximum is shown by inshore swarming along the water's edge. The specimens were mainly obtained by wading in November and in the early part of December.

The population, when most abundant, consists mainly of young forms. The number remains few from the later part of December till May, and falls to the minimum in September and October.

It is a striking feature in the distribution of the size-groups that the young forms are abundant throughout most part of the year, while the number of the mature forms remains low. This probably suggests the general behaviour of the different age groups. Observations show that the adults incline to cling tightly to the lower parts of Laminaria plants with their legs; the number of the adults caught depends mainly on the amount of uprooted plants in the net. The number caught is further reduced by the necessity of avoiding the rough ground adjacent to the breakwater. The young forms are active swimmers and show preference for detritus in the laboratory condition. This might be true of the behaviour of the young forms which under natural conditions disperse over a wider area and thus appear in large numbers in the samples.

Reproduction   Ovigerous females were collected throughout the year except in February and June. It is believed that the breeding season of I. emarginata is continuous throughout the year. The bulk of ovigerous females were obtained in the beginning of July. The number decreases in August and September, and increases again towards December.

Jacke (1924) shows that in Asellus aquaticus, the number of fertilised eggs is reduced from 150 to a brood of 8, two lots of embryos being expelled. Howes (1939) finds that the reduction of the number of eggs or embryos in Idotea viridis is due to different hatching periods. The present work has been done with a full awareness of the possibility of the expulsion of hatched larvae at different periods. Ovigerous females carrying advanced stages of embryos were sorted as a separate group. The number was found to be negligible compared with the total number and was excluded from the present data.

The size of the ovigerous females and the number of eggs or embryos in the brood pouch show the same tendency as the other forms in the Bay in correlation to the season. 35 ovigerous females, measuring 11-18 mm., were obtained on 4.V.50. Out of these, the number of eggs or embryos in the brood pouch of 33 were counted.

Table 20. Idotea emarginata. Size composition of the ovigerous females and number of eggs or embryos in the brood-pouch in the months April, November and December of 1949, and May and July of 1950.

Body Length (in mm)	Date / No. of Individuals: April 20 (1949)	Dec. 16 (1949)	May 4 (1950)	July 7 (1950)	July 28 (1950)
8		1		3	
9				15	7
10		1		42	21
11	3	5	3	23	14
12		3	6	7	8
13	1	1	6	3	
14			3	1	
15			9	2	
16			4	1	
17		1	2	1	
18			2		

No. of eggs or embryos in brood pouch	Date / No. of Individuals: April 20 (1949)	Nov. 24 (1949)	Dec. 16 (1949)	May 4 (1950)	July 7 (1950)	July 28 (1950)
20-24					2	2
25-29					3	
30-34		2			5	2
35-39	3	2	1		7	6
40-44		3			5	4
45-49	1	1			9	4
50-54		1	2	1	9	3
55-59		1	1	4	10	5
60-64		9		1	7	2
65-69		6	1	3	8	
70-74		2	2		3	
75-79		2		2	5	4
80-84		2	2	2	2	
85-89		1		2	2	
90-94		1		2	2	
95-99		2		1		
100-110		1	1	4	1	1
111-120		2	1	1		
121-130				3		
131-140				3		
141-150				2	1	
151-160				1	1	
167					1	
233				1		

From Table 20, it is shown that the number of eggs or embryos carried by these ovigerous females falls almost equally into 2 groups, 50-100 and 101-151, with one exception of 233. One hundred ovigerous females were measured from the sample of 7.VII.50. The size ranges from 8 to 17 mm., with a modal size group of 10-11 mm. The number of eggs or embryos in these females range from 22-90 with four exceptions of 109, 146, 156, and 167 respectively. The reduction of both the size of the ovigerous females and the number of eggs or embryos in the brood-pouch is obvious in July. The condition remains the same throughout the winter maximum. The results suggest the possible existence of two groups of ovigerous females with a possible demarcation in April. Those that breed in the early part of the year are bigger in size and have larger numbers of eggs or embryos, while those that breed in the later months are smaller in size, with lesser numbers of eggs or embryos.

Feeding habits As has been already mentioned, I. emarginata feeds mainly on Laminaria digitata. Experiments have been attempted to determine the difference of feeding habit of I. emarginata between day and night, and the amount of frond consumed daily by each Idoteid. Mature males and ovigerous females were selected from a living stock. The individual specimen was measured and weighed (excess water on the body was 'dried' with a piece of blotting paper) and kept in a separately numbered breffet. A Laminaria frond was cut in 2 cm. pieces, weighed, (excess water was blotted) and introduced into the breffet which contained the Idoteid. Controlled pieces of Laminaria frond were kept in the same condition. The frond was weighed again after 12 hrs. when the breffets were placed on the circulation bench under the ordinary indoor light intensity. The breffets were transferred to the dark room and after 12 hrs. the weighing of the frond was repeated. The results, as shown in Table 21, suggest that the amount of frond consumed in darkness is higher than that consumed under daylight. It also indicates that the Idoteid stops feeding both before and during moulting. The amount of Laminaria consumed related to the body size of the Idoteid and the water temperature, needs further investigation which has not been possible in the present work.

Diurnal movement The free-swimming population is bigger after dark than in the day-time during the months from August to November (Table 22). The samples of November further show their relationship with tides for the number caught increases at high water, especially after dark. The diurnal movement is not conspicuous in the summer months. The numbers show a constant maximum in the early morning and a considerable decrease during the day-time. The abundance is variable after dark. Only two samples (28.VII.50 and 21.VIII.50)

Table 21. Amount of Laminaria frond consumed by Idotea emarginata.

Water T°C Body Length in mm.	Sex	'Dried' Body wt. (in mg.)	No. of Individuals	'Dried' Laminaria Consumed 12 hrs. in darkness 5.VI.50	12 hrs. in daylight 6.VI.50	12 hrs. in darkness 7.VI.50
32	♂	665	1	92	15	25
31	♂	592-650 Av. 619	3	85-115 Av.100	11-50 Av. 30	25-55 Av. 38
30	♂	490	1	55	25	15
26	♂	325	1	50	25	50
25	♂	260-320 Av. 290	2	5x	0o	5*
18	♀	155-165	3	5-30 Av.21	15-25 Av.20 1 moulting°	25-35
17	♀	150	1	27	25	10
16	♀	115	1	0x	0o	15*

Remarks. x - amount consumed before moulting.
o - amount consumed during moulting.
* - amount consumed after moulting.

Table 22. Idotea emarginata. Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day. H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	2 (L.W.)	2 (H.W.)	2 (L.W.)	17 (H.W.)
30 Oct.	0 (H.W.)	5 (L.W.)	17 (H.W.)	8 (L.W.)
24-25 Nov.	13 (L.W.)	98 (H.W.)	76 (L.W.)	1180 (H.W.)
1950				
4 May	120 (L.W.)	11 (H.W.)	173 (L.W.)	55 (H.W.)
21 May	37 (L.W.)	85 (H.W.)	11 (L.W.)	8 (H.W.)
7 July	8485 (H.W.)	546 (L.W.)	23 (H.W.)	39 (L.W.)
28 July	1069 (L.W.)	52 (H.W.)	288 (L.W.)	381 (H.W.)
21 Aug.	12 (H.W.)	3 (L.W.)	17 (H.W.)	76 (L.W.)

show a slight increase in number after dark. The young forms show more extensive horizontal movement in May; the movement is limited to the deeper part of the Bay towards the end of June.

Idotea baltica (Pallas)

General occurrence This species is common but by no means abundant, except at its swarming period in November and early part of December. Its distribution in the Bay shows its tendency to wander to the intertidal area in the months from November to May, and to be an inhabitant in shallow water, especially along the lifeboat slip, in the months of July and August. The number in the swarming period increases invariably on the flood tide, especially after dark. In the months of January, March and May, the individuals along the water's edge consist largely of young forms, measuring 3-5 mm. and 6-9 mm., and small numbers of males, 10-14 mm. and 15-19 mm. In July and August the mature forms and ovigerous females are confined to shallow water and only young forms occur in the intertidal area.

Seasonal abundance The seasonal frequency of I. baltica differs from that of I. emarginata in the absence of a summer maximum. The number increases considerably in November and reaches its maximum in the early part of December (Fig. 14). The abundance of I. baltica alternates in time with that of I. emarginata. Its number was higher than that of I. emarginata in the months from November of 1949 to March of 1950, but decreased in the summer months while that of I. emarginata reached its maximum. Ovigerous females of this species are scarce in the early part of the year, and do not increase till the end of July. The rarity of ovigerous females in the samples from January to May, might account for the absence of a summer maximum of this species.

Reproduction Ovigerous females have been obtained in all months except February and April; the number is small for the most part of the year, the bulk being obtained in July, October and November.

Small numbers of young forms occur throughout the year and show a maximum abundance in November and December.

Diurnal movement The difference in number between day and night catches is not consistent, except that in October and November the number in the night hauls is considerably higher than that in the day haul. (Table 23). The samples in November further show that the number is related closely to tides and light intensity, the number being invariably higher at high water and especially after dark. Samples of the summer months show a tendency to increase in number in the early morning.

Table 23. Idotea baltica

Summary of Data showing the number of individuals obtained at different states of the tide at different periods of the day. H.W. High Water; L.W. Low Water.

DATE	NUMBER OF INDIVIDUALS PER PERIOD OF THE DAY			
	Morning	Daylight	Evening	Midnight
1949				
25-26 Sept.	9 (L.W.)	26 (H.W.)	7 (L.W.)	22 (H.W.)
30 Oct.	4 (H.W.)	15 (L.W.)	61 (H.W.)	28 (L.W.)
24-25 Nov.	15 (L.W.)	95 (H.W.)	57 (L.W.)	1387 (H.W.)
1950				
4 May	27 (L.W.)	18 (H.W.)	8 (L.W.)	12 (H.W.)
31 May	7 (L.W.)	16 (H.W.)	17 (L.W.)	18 (H.W.)
7 July	31 (H.W.)	6 (L.W.)	0 (H.W.)	25 (L.W.)
28 July	75 (L.W.)	57 (H.W.)	4 (L.W.)	59 (H.W.)
21 Aug.	144 (H.W.)	107 (L.W.)	15 (H.W.)	2 (L.W.)

Idotea viridis (Slabber)

Rare. Specimens were obtained along the water's edge at low water in April and December, in the intertidal zone in May and August, and adjacent to the breakwater in June. The numbers in the samples, with the exception of those obtained on 30.VIII.49, are too insignificant to indicate the distribution of this species in the Bay. The occurrence of 35 young forms, measured 3-5 mm., on 21.VIII.49 was an isolated event which showed no connection with the previous samples. Other records from the Bay show that this species frequents the buoy. Specimens have been obtained from 2 buoys that were washed up in Port Erin on 3.XI.48.

Howes (1939) records that this species is common in a saline lagoon in Essex and shows summer maximum in June-July and winter maximum in December. Watkin (1941) suggests that this species is migratory throughout the year in Kames Bay and appears to be numerous in February, May and November.

Idotea linearis (Pennant)

Rare. 15 specimens were recorded in the months from May to September in the region between the life-boat slip and the breakwater. One juvenile has been obtained about the mid-tide level after dark. Ovigerous females were obtained in June of 1949 and 1950.

Idotea neglecta G. O. Sars

This species is fairly common in the Laminaria bed inside the breakwater, but rare elsewhere in the Bay. Its occurrence at a particular site is believed to be for the same reason (i.e. feeding) as that of I. emarginata. There is no distinct movement of large numbers to the water's edge in any period of the year. Hitherto only 3 immature specimens, measuring 10-13 mm., have been obtained along the water's edge, on 9.XII.49. The present material is not sufficient to determine the exact period of the seasonal abundance. A total of 18 ovigerous females, obtained on 4.V.50, and a sample of 70 young forms, measuring 6-9 mm., obtained on 7.VII.50, suggest the possible maximum abundance period to be in June.

Ovigerous females were obtained in May, July, September, October and December. 8 ovigerous females, collected on 7.VII.50, were measured, 11-13 mm., and found to be carrying 59-92 eggs.

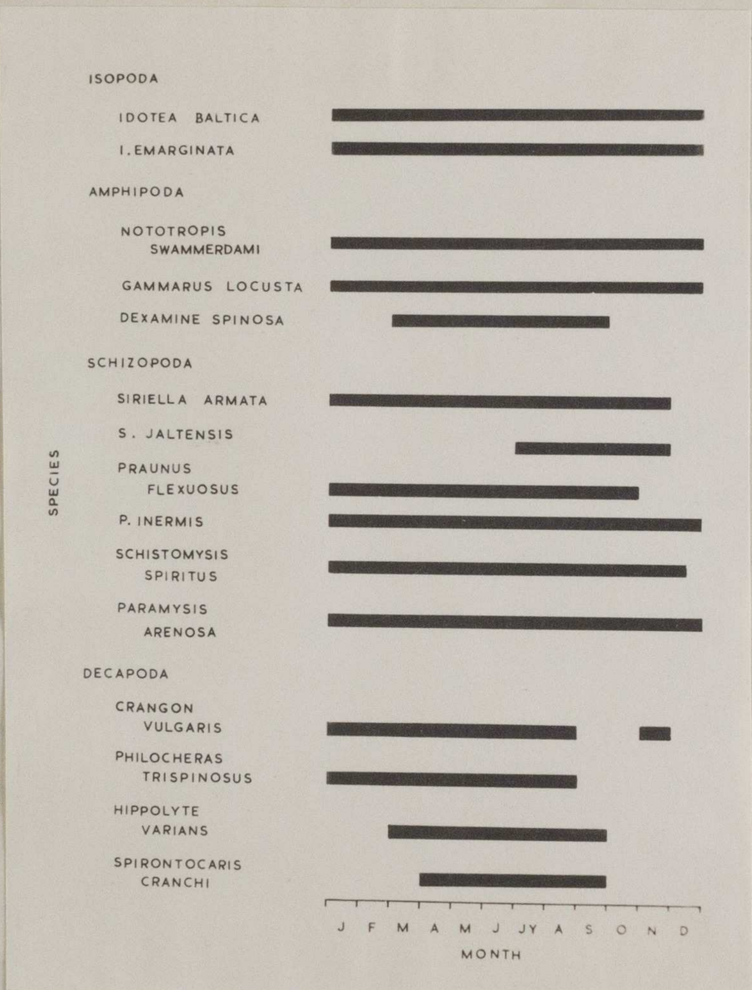


Fig.15 Occurrence of ovigerous females of some species of Crustacea Malacostraca in Port Erin Bay.

DISCUSSION

Breeding period The sublittoral custacea, as shown in Fig. 15 may be roughly divided into two categories, according to the length of their breeding period in the year: (i) Schizopoda, Amphipoda and Isopoda breed for more than 10 months and (ii) Decapoda Natantia breeds for less than 10 months. The classification of these groups does not distinctly follow with the habitats of the different species.

The factors controlling the breeding of the Crustacea Malacostraca are not yet fully understood. The results how that the breeding biology varies considerably among the different species. The organisms of each group share some common characteristics, yet each species has its own peculiarities. It seems that the biological factors as well as the environmental factors that act through the former, are of equal importance.

Orton (1920) states that food and salinity variation under normal conditions can be eliminated as factors pre-eminently controlling breeding, and hence, "it was deduced that sea-temperature must be an influence of paramount importance controlling breeding in marine animal ..... Most animals under normal conditions begin to breed either at a definite temperature, which is a physiological constant for the species, or at a definite temperature change, namely at either the maximum or the minimum temperature of the locality."

The present results show that the breeding of the different Crustacea groups corresponds differently to the temperature. The breeding season of Idotea emarginata, Gammarus locusta and Siriella jaltensis extends throughout the year; the summer and winter maximum of the ovigerous females in July and November - December respectively corresponds closely with the maximum and minimum temperature of the year. This agrees with Thorson's (1946) "observation on the larvae of Polydora ciliata which may occur in Sound in March as well as late in the summer, i.e. during periods with pronounced minimum and maximum temperature." In Decapoda, with the exception of Crangon vulgaris, the breeding period extends from March to September, obviously corresponding to a definite range of temperature.

In the Mysidae, the ovigerous females of Schistomysis spiritus, Paramysis arenosa and Parunus inermis are found throughout the year. The only exceptions are Praunus flexuosus and Siriella armata; of the former the ovigerous females occur from January to October and of the latter they occur from November to January. It is evident that these species breed almost in all ranges of temperature, except during a very short quiescent period. The quiescent period of Schistomysis spiritus extends from the latter part of December to the early weeks of January. In Praunus flexuosus and Siriella armata the quiescent period lasts respectively from October and November to January. It is interesting to note that these species start to breed at a lower temperature as compared with that towards the end of the breeding season.

As shown among these species, temperature apparently has a slight influence on the breeding cycle. Thorson (1936, 1946) shows that he finds "a few examples of cases in which the temperature is without any influence at all as a direct inducer of spawning in Marine invertebrate." He gives the evidence that "breeding in Mya and Sacicava, though distinctly limited to the summer season, set in on a large scale much earlier than the rise of temperature."

Diurnal Movement Correlated with Light and other Factors.

It has been shown in the previous sections that the crustacea in Port Erin Bay show different degrees of diurnal movement, depending primarily on the species. Rose (1925) and Russell (1927) review previous works on the vertical movement of plankton in the sea and draw the conclusion that light is usually the factor of greatest importance.

The Crustacea Malacostraca in the Bay can be divided into three groups, according to the nature and extent of their diurnal movement in response to the light: (i) the mysids - free-swimming forms which perform diurnal movement either vertical or both vertical and horizontal,

(ii) the decapods - bottom-living forms of which some species perform horizontal movements,

(iii) the isopods and the amphipods - bottom-living forms which perform diurnal movements only at certain periods of the year.

Most species of mysid show a much greater tendency to perform diurnal vertical movement than the other forms. Russell (1925, 1928, 1931, 1933) shows that certain off-shore mysids at Plymouth, such as Anchialina agilis, Leptomysis gracilis, Neomysis longicoris, Schistomysis sp., Erythrops sp., and Gastrosaccus normani, move upward from the bottom with the approach of darkness to the mid-water, and that some species such as Anchialina agilis move to the surface itself in some numbers. Tattersall (1936) further shows that of the mysidacea on the Great Barrier Reef, (i) Anchialina typica and Promysis orientalis exhibit diurnal movements, being found in the deeper layers by day and rising to the surface by night, (ii) at night the population of mysids in the plankton is augmented by numerous species which are apparently bottom-living by day and become planktonic at night. It is evident that both inshore and offshore mysids agree, in general, in a vertical movement with the alternation of darkness and light, which is in accord with the rhythm of the diurnal cycle.

Foxon (1940) observes the reaction of Hemimysis lamornae to light under laboratory conditions and assumes that "the rising at night is due to negative geotaxis which is reversed and becomes positive in the presence of light" and that the influence of light appears to act through geotaxis.

Foxon's assumption that the vertical movement of mysids is a result of the interaction of light and gravitational stimuli, can be applied to Schistomysis spiritus, Siriella jaltensis and Siriella armata. However, some species, such as Praunus inermis and P. flexuosus do not seem to follow the rule, judging by their remaining in or near the bottom layer of water throughout the diurnal cycle in the natural condition. Thus it is reasonable to suppose that other factors besides light and gravitation might affect the movement of these species. This assumption finds further substantiation in Jenning's (1909), (and in Franz, 1911) suggestion that "these orienting reactions present no more ground for characterisation as uniform, simple, elemental or direct, than do the reactions belonging to the other descriptive categories, such as food reactions."

The horizontal movement of some species to the water's edge as shown by Schistomysis spiritus and Siriella jaltensis and S. armata, is presumably influenced by the tidal movements. The young forms of Schistomysis spiritus move to the edge of high water during daytime in the summer months, and those of Siriella armata in September. The adults of Schistomysis spiritus perform horizontal movement in the early morning and late evening till dark and those of Siriella jaltensis after dark. The factors controlling the movement, apart from the tidal effect, seem to differ in the nature of geotaxis between the daytime and the night. It is controlled by a combination of light stimulus and positive geotaxis in the daytime and entirely by negative geotaxis after dark. The species which live away from the intertidal water, such as Siriella jaltensis, obviously move upward to the surface after dark and then drift shoreward with the tide.

The influence of artificial light upon the night migrants of certain inshore mysids has been shown by Fage (1933). He collected crustacea from the surface by artificial illumination from an immersed electric lamp in the sea at Banyuls, and from an acetylene lamp floating on the surface of the sea at Concarneau. He shows that the light has enabled him to obtain a number of mysids such as Siriella armata, S. clausi, S. jaltensis and Schistomysis spiritus. He suggests that the illumination at night has both quantitative and qualitative effects by increasing the number, by concentrating the organisms in a smaller area, and luring a greater variety of species, some of which normally stay below the surface in darkness. It is known that artificial light under laboratory conditions produces a positive phototactic effect on most plankton animals which under natural conditions are negatively phototropic to daylight. This contradiction has been solved by Russell (1927) by taking the intensity of light into account. He assumes that Calanus "may have as its optimum intensity in nature a value as much as 10,000 metre-candles. It is obvious then that in the laboratory the intensity may be well below its optimum, which would account for its positive phototropism." This interpretation may be applied to Fage's work under natural conditions, that strong artificial light has the same positive phototactic effect on the mysids that swim below the surface in darkness. Weak light, in such cases, seems to have no influence on the orientation of the mysids and thus they tend to maintain the negative geotaxis.

Diurnal movements have been shown to be correlated with the breeding cycle in many species of mysids. Fage (1933) has brought forward some examples at Concarneau to show that "la migration verticale ne se produit d'une façon régulière que durant le temps de l'activité sexuelle". Tattersall (1936) has shown that the occurrence of Anchialina typica and Promysis orientalis in the day townetting on the Great Barrier Reef "coincides with the breeding season of the two species concerned."

The present work does not agree positively with the results of the above workers so far as the breeding activity of the mysids at Port Erin Bay is concerned. The ovigerous females of Schistomysis spiritus and Siriella jaltensis were found in the surface tow net only in July and August. Judging from the continuous breeding period of these two species throughout the year and the brief occurrence of the ovigerous females in the surface tow net, it seems that explanations other than Fage's are necessary. It is noted that the occurrence of the ovigerous females of these species on the surface coincides with the highest temperature of the year (14.9°C). This seems to suggest that high temperatures might influence the upward movement of these species. Ewald (1912) states, "increase of temperature made (geotactically) positive animals negative and negative animals more negative .....".

Fage's work (1933), as has already been pointed out, is based on the material collected from the surface with the aid of artificial light, and, furthermore, his conclusion is drawn in many cases from observations upon small numbers of specimens, such as his collections of Schistomysis spiritus and Gastrosaccus spinifer, as shown in his tables amounting to 77 and 41 individuals respectively. In these cases, his records on the breeding period of the sublittoral crustacea might represent only partly the actual breeding activity and thus could hardly be regarded as having a bearing on the vertical migration of these species.

Most decapods pass through two phases: a series of planktonic larval stages and a benthic life after metamorphosis. Under laboratory conditions, Pandalus larvae are positive phototropic (Spooner, 1933), but in the natural surroundings they are not. Russell (1925, 1927, 1928) has shown the difference in the diurnal movement between the larvae of Pandalids and Processa canalicuta, on the one hand, and Crangonid larvae on the other. The former were taken in large numbers below 15 metres and showed slight vertical movement after dark; the latter "showed a consistent preference for the deeper layers below 20-25 metres in the daytime" and a definite upward movement after dark.

The adult forms perform horizontal movement to a certain extent but no vertical movement has been observed. The marked increase in number of the population of Spirontocaris cranchi and Processa canaliculata at night, suggests the horizontal movement of these species, moving probably from a rocky and weedy sublittoral zone to the sandy region, in the case of the former, and from offshore to inshore water in the case of the latter. The cause of this movement is not certain. It might simply be a nocturnal excursion similar to those of nocturnal terrestial animals that emerge from their immediate habitats after dark to forage in the vicinity for food, retreating again to their habitat with the approach of daylight. The self-burial of most Crangon vulgaris and Philocheras trispinosus in the sand in the daytime and their foraging emergence after dark, might be another mode of changing habitat in accordance with the diurnal cycle. It might thus be assumed that adult Decapods are benthic forms presumably with positive geotaxis that tends to overpower whatever other factors might exist, and thus determines the movement of these animals.

The sublittoral isopods and amphipods share the general character of the benthic forms which show little movement with the diurnal cycle, except the young forms and adult males of some species which seem to move diurnally in certain seasons. A few young forms are occasionally found to perform the diurnal vertical movement while their horizontal movement in winter and spring months show no connection with light intensity. The swarming of all size groups along the water's edge coincides with stormy weather and with the appearance of detritus along the water's edge in the winter months.

The most striking feature of the diurnal movement of amphipods is the predominance of adult males of some species in the surface townetting at night in summer and autumn. It is interesting to note that the results are similar to that of Fage (1933) at Concarneau with the aid of artificial illumination. Fage explains the predominance of the males as follows: "Les mâles --- nous l'avons noté --- pourvus d'yeux mieux développés que ceux des femelles, sont plus sensibles à cette influence et se trouvent ainsi attirés en foule autour du foyer lumineux."

His theory on the higher sensitivity to light of the well-developed eyes of the males may be applied to the present observation. It is probable that the male amphipods have an optimum light intensity, and when light intensity is reduced at dusk they move towards the surface and remain on the surface after dark when the stimulus of light is removed. This suggestion has been put forward by Michael (1911) to explain the diurnal vertical movement of Sagitta bipunctata, and by Russell (1927) on the vertical distribution of plankton.

Fage (1933) distinguishes between the diurnal movement of Cirolanidae and Idoteidae. With the former, the pelagic phase effects only the males and the young forms, while the ovigerous females remain always at the bottom; the latter stay on the substratum during the day, and at night, "thigmotropism" being obscured, young males and adult females swim actively on the surface. Fage's collections show "au moins pour Idotea baltica, ces réactions sont identiques dans les deux sexes à tous les stades de leur évolution."

Strong indication in favour of this distinction between the two groups is shown in the present observations. However, the thigmotropism governing the pelagic migration does not seem to exist as a sole character among Idoteidae; as has already been mentioned, Idoteidae do not show regular movement either horizontal or vertical in accord with the diurnal cycle. The swarming along the water edges in winter can only be regarded as a seasonal movement as it can also be found among sublittoral amphipods such as Gammarus locusta and Nototropis swammerdari, inhabiting the same localities as Idoteidae. It is more likely from the community viewpoint, that other physical factors such as stormy winds and the occurrence of detritus along the water's edge might influence all the inhabitants in common and thus become motive forces in their movement.

Comparison of Crustacea Malacostraca of the Intertidal and Sublittoral Zone.

The distribution of different species of crustacea on the sandy beach, with reference to their relative abundance and the approximate tidal level where the dragging samples were collected, show distinct zonations:

(i) those such as Eurydice pulchra that occur from high water neaps to mid-tide level,

(ii) those such as Bathyporeia pelagica that occur along the mid-tide level,

(iii) those such as Pontocrates arenarius and P. norvegica that are abundant between the level of low water neaps and low water springs.

The results agree with samples obtained by digging at the same localities (Jones, 1948), and the data given for Kames Bay, Millport, by Watkin (1941). The density of population seems to show that Bathyporeia spp. and Pontocrates norvegica are more abundant in Kames Bay, while Eurydice pulchra and Pontocrates arenarius are more abundant in Port Erin, while Bathyporeia pilosa is completely absent in the latter locality. Jones (1948) assumes that the absence of B. pilosa at the latter locality "may be due to the absence of suitable ground above H.W.N.T."

The physical factors controlling the zonations in the intertidal area are not understood. The conditions have been suggested by previous workers as follows:

(1) Shelter. Jones (1948) suggests that the intertidal distribution of some amphipods is regulated by the amount of shelter available. Nevertheless, it is unlikely that there should be any difference in the degree of shelter afforded by the different tidal levels on Port Erin beach, with the exception of the harbour area which is sheltered by the pier.

(2) Salinity. Pirrie, Bruce and Moore (1932) find that the salinity contour on the beach of Port Erin Bay varies in a number of gradations: (i) 30-32% towards the south and north ends of the beach; (ii) 28-30% and 24-28% in the regions running respectively along and across the fresh-water streams which spread fan-wise from about the middle of the Bay towards the low-water mark, this isohaline contour extending to the harbour area;

(iii) below 24% on the beds of fresh water streams. Their results show that no close correlation can be traced between the distribution of the fauna and the salinity of the beach.

(3) Exposure at Low Water This has an obvious effect on the distribution of the species in the intertidal zone. The marked differences in the period of exposure to the air and heat in the high water level between the consecutive tides will directly effect other environmental factors such as salinity and food supply which consequently influence to a certain extent the animals inhabiting this area. Experiments on the amplitude of the duration of exposure in connection with the physiology of different species will, probably, throw light on this problem of zonation. Holme (1949) suggests that the "intertidal distribution of *Eurydice pulchra* is perhaps related to the degree of drainage of sand." It seems that *Eurydice pulchra* and *Bathyporeia spp.* can tolerate long periods of exposure to the air while *Pontocrates arenarius* and *P. norvegicus* prefer to be practically submerged in the water.

The crustacea in the sandy sublittoral zone, except for mysids that swim close to the bottom layer of water, are bottom-living forms. In assessing the habitat of different species, three areas may be distinguished:

(1) the area immediately below the intertidal zone, to a depth of 1 metre, characterised by bare sand substratum and frequently concentrated patches of detached sea-weeds. The crustacea in this community include those both of the intertidal zone and of the shallow water, with *Schistomysis spiritus* predominating and *Crangon vulgaris* coming second. The abundance of animals in this area is extremely variable with the flooding and the ebbing tides.

(2) the area of shallow water from 5-10 metres deep in low water, consisting of bare sand in winter but covered with a thick settlement of algal fragments in summer. The dominant crustacea are *Pandalus montagui*, *Praunus flexuosus*, *P. inermis*, *Hippolyte varians*, *Dexamine spinosa*, *Gammarus locusta* and *Idotea spp.*

(3) the area immediately below the tidal edge along the north and the south sides of the Bay, characterised by a rough substratum, either rocky or intersected by large boulders, thickly vegetated with sea-weeds. Some crustacea in this region occur also in area (2), for example:

Praunus spp. and Hippolyte varians, but Pandalus montagui is replaced by Leander serratus, Spirontocaris cranchi and Athanas nitescens. This area includes a narrow strip of water on the south-west end immediately inside the ruined breakwater, characterised by scattered boulders from the ruin and a thick growth of Laminaria digitata; Idotea emarginata, I. neglecta and Gammarus locusta are here abundant.

It is apparent that the habitats of the crustacea in the sublittoral zone exhibit different communities under different environmental conditions though there is no rigid boundary for some species. Jones (1950) reviews the previous works on the marine bottom communities and attributes the community differentiation to the following causes: (i) temperature, (ii) salinity, (iii) bottom deposit, (iv) morphology and mode of life, and (v) mode of feeding.

The bottom water temperature of the Bay shows differences of about 2.6, 5.2, and 0.4°C respectively in May, June and July between the area close to the water's edge and the shallow water, while there is no significant difference in winter. The optimum temperature which each species favours and the temperature limit which effects the distribution of a species are still obscure. It seems very unlikely that the distribution of a species could be restricted to a very narrow range of temperature as shown by the temporary regional difference in the Bay in summer, but on the other hand when the temperature decreases in winter, most species in areas (1) and (3) are confined to the same habitat, though the number of the population shows sharp decrease. The only known exception is the offshore migration of Pandalus montagui and Crangon vulgaris which might be due to the combination of temperature and other physical factors, such as the stormy weather and the disappearance of detritus from shallow water.

The salinity along the L.W.M. in the Bay varies from 23.2 to 30.8‰ and is low as compared with 33.0 and 33.4‰ in the Irish Sea (Pirrie, Bruce and Moore, 1932). It must be mentioned however that the low salinity in this region is only temporary and soon changes to the higher salinity of the flowing tide. Thus it is unlikely that salinity could be a determining factor in the distribution.

The nature of the substratum does not show direct relation with the bottom-living crustacea in the sublittoral region, except for the crangonids that bury themselves in the sand during the day. Other species associate directly with the vegetation growing on the substratum which either affords the food source or the shelter for the species. This inclination is more obvious in winter when the bottom of the shallow water becomes completely bare.

The mode of feeding seems to be a most important factor in determining the habitat of certain species. The mysids, Praunus flexuosus and Hemimysis lamornae exhibit two types of feeding, (i) catching large food masses and (ii) collecting suspended particles, (Depdolla, 1923, Cannon and Manton, 1927). It is probable that the feeding of other mysids would not show much difference. Schistomysis spiritus, as shown both in the field and laboratory observations, feeds mainly on food masses. This probably could account for this species living close to the water's edge, where the food particles are constantly churned up by the waves. Crangon vulgaris is mainly a carnivore, thus the region close to the low water edge provides an ideal feeding ground with its abundant supply of Schistomysis spiritus and other amphipods and polychaetes which mainly constitute its food.

The occurrence of crustacea in the shallow water area coincides with the accumulation of algal fragments on the bottom in calm weather, thus producing a summer maximum and a winter minimum both for amount of weed and for abundance of crustacea. Hjort and Rudd (1938) show that Pandalus occurs in greatest abundance when the bottom is sufficiently quiet for organic debris to settle. Dahl (1948) points out the amount of detritus present may control the distribution of certain species of crustacea living on algae.

It is highly probable that Pandalus montagui, Hippolyte varians, Dexamine spinosa, Gammarus locusta and Idotea baltica are detritus feeders. A close examination of the feeding habits of these species will furnish a better understanding.

It has been shown that Idotea emarginata, I. neglecta and Gammarus locusta establish themselves in a particular community with a favorable combination of food supply and shelter inside the breakwater. The breakwater ruin, which stretches about a third of the distance across the Bay, evidently affords a good deal of shelter from heavy seas, especially from westerly gales in the winter months. The absence of shelter elsewhere probably explains the scarcity of Idoteidae from other laminaria beds in the Bay.

These species associate also partly with algal fragments in the shallow water, as shown by the occurrence of ovigerous females and large numbers of newly hatched young forms in the detritus in July. The large males, on the other hand, are confined to the _Laminaria_ bed under the breakwater, where they occur in large numbers. It is highly probable that the newly hatched young forms are detritus feeders and the adults are frond feeders.

The swarming of the sublittoral isopods and the amphipods along the water's edge in the winter months seems to be a combined effect of wave action and the occurrence of algal detritus. During stormy weather, the waves churn up the bottom of the shallow water and drift the algal fragments to the water's edge. The species, such as _Gammarus locusta_ and _Nototropis swammerdami_, that are usually seen riding on the algal fragments, will be drifted to the water's edge with the tide. The main population obviously moves in after dark, especially at high water, as indicated by a marked increase in number.

It has been shown that the occurrence of _Gammarus locusta_, _Idotea baltica_ and the young forms of _Idotea emarginata_ in certain areas corresponds closely with the settlement of detritus in the spring and summer months. Apparently the swarming is a movement connected with the drifting in of the detritus.

Seasonal abundance

The number frequency of most species of Crustacea Malacostraca shows a maximum either in July or in September and a minimum in winter. A few show two maxima, respectively in July and in early winter.

Those species with a maximum in July includes *Praunus inermis*, *Schistomysis spiritus*, *Paramysis arenosa* and *Crangon vulgaris*; the species in September are *Hippolyte varians*, *Spirontocaris cranchi*, *Pandalus montagui*, *Praunus flexuosus*, *Siriella armata*, *S. jaltensis*, *Dexamine spinosa*, and those with a July and a winter maxima are *Idotea baltica*, *I. emarginata* and *Gammarus locusta*.

A notable feature of the maximum population of allthe species is the predominance of the young forms, while the ovigerous females in many species constitute the bulk of the mature forms. These facts indicate a close relationship between the seasonal abundance of a species and its breeding phenomena, such as (i) the number of the ovigerous females at the beginning of the breeding season, (ii) the duration of the incubation period and the size as well as the number of broods throughout the season, and (iii) the mortality of the larvae during the metamorphosis.

The early attainment of the maximum abundance in July seems a result of the great number of the ovigerous females in the early months. This assumption is substantiated by the influx of the ovigerous females of *Schistomysis spiritus* and the comparatively large number of the ovigerous females of *Praunus inermis* and *Paramysis arenosa* at the beginning of the breeding season, as contrast with the small number of ovigerous females of *Praunus flexuosus* and *Siriella armata*. The number of the ovigerous females of *Praunus flexuosus* remains comparatively small till July, while that of *Siriella armata* till August.

The reproduction of Decapod Natantia differs from that of mysids in many respects. As shown in the following table, the breeding of the former is characterised by (i) the enormous number of eggs in each brood, (ii) the great length of the incubation period and of the sexual maturation of the young, and (iii) the long pelagic life of the larvae during metamorphosis. The great length of the incubation period delays the increase in population of a species to a considerable size in the early months and the long period for the young individuals to reach sexual maturity restricts the increase of the breeding stock.

Species	Age of sexual maturity (months)	No. of broods	No. of eggs in each brood	Brooding period (weeks)	No. of larval stages	length of pelagic life (weeks)	Breeding period	Authors & Date
Crangon vulgaris	12	3	1500-14000	4-13	5	5	March-Apl. June - summer Sept.-Feb. winter	Ehrenbaum (1890) Havinga (1930) Meyer (1934,1935) Lebour (1931)
Anthanas nitescens				2 (16-17 days)			May - August	Nouvel (1935,1937)
Hippolyte varians				2 (12-13 days)	5		June- Aug. (Roscoff) June- Sept. (Norway)	Nouvel (1937) Nordgaard (1912) Bate (1856)
Pandalus montagui							March - June	Wollebaek (1908)
Pandalus borealis				20(Norway) 24-32 (W.Green-land)		12 16		Hjort & Ruud (1938) Stephensen (1935)
Leander squilla	12	2		4(23°C) 8(11°C)	5	4		Elmhirst (1921) Nordgaard (1912) Nouvel (1937)

The larvae of Decapods are supposed to suffer a high mortality because of their long pelagic life. The survival rate is conditioned by many factors, such as temperature, the amount of food, the presence of predators, and a suitable settling ground. There can hardly be any doubt that a large stock of the larvae perishes before the completion of metamorphosis. Thorson (1946) shows that in Danish waters "species with great fluctuation from year to year have planktotrophic larvae with a long pelagic life while species with a great stability of occurrence have a very short pelagic life or a non-pelagic development".

The abundance of most decapods in the Bay apart from the breeding conditions depends partly on the number of adults moving into the Bay, presumably from the adjacent regions, but the size of the population is believed to depend mainly upon the number of young settled individuals which are hatched from successive broods during the breeding period.

The scarcity of most species of Crustacea Malacostraca in Port Erin Bay in the months from January to April or May is possibly due to the unfavourable conditions in that period. The low temperature and the strong wind in these months might be the factors of the high mortality of many residential species and of the offshore migration of some species, such as Pandalus montagui, and Crangon vulgaris.

Food of Inshore Feeding Coal Fish (Gadus virens)

Source of Material

The present study is mainly devoted to the feeding habits of the coal fish collected in Port Erin Bay. The material was collected mainly by seine-netting at the beach of the Bay at all states of tides after dark, and occasionally in the day-time. Small numbers were caught by drift net and angling. Both coarse and fine mesh seine net were employed during the first year. The coarse mesh-net was the main one used, measuring 62 metre in length and 5 metre in depth, attached with 112 metre of rope at each wing, with the mesh measuring 5.5 cm. when stretched. Naturally the catches were bound to be of the large size groups. In the second year, the fine mesh seine net, measuring 56 m. in length and 2 m. in depth, with the mesh 2.2 cm. on the wing and 1 cm. toward the pocket, was used in addition, so that the catches included all size groups. The frequency of sampling varied from 2 to 4 times a month. The catches in winter were usually bulky and a sub-sample of 20-40 specimens was examined. All the specimens in the small samples were examined.

Method and Technique

The specimens were first washed with fresh water and drained, and then measured to the nearest 5 mm. from the anterior tip of the premaxilla to the base of the caudal hypural. The body was weighed to the nearest 0.5 gm.

The food has been analysed both qualitatively and by weight. The contents were weighed to the nearest 50 mg. with the mucus and the parasites excluded. Each stomach was dissected and the contents were collected on a petri-dish with one drop of 40% formalin added. The contents were then preserved separately and examined within two or three weeks. Each food species was identified under a dissecting microscope and the number of "whole animals" and"partly digested animals" were counted separately. The weight of each food species in in the stomach contents was estimated from the weight of preserved specimens collected in the Bay.

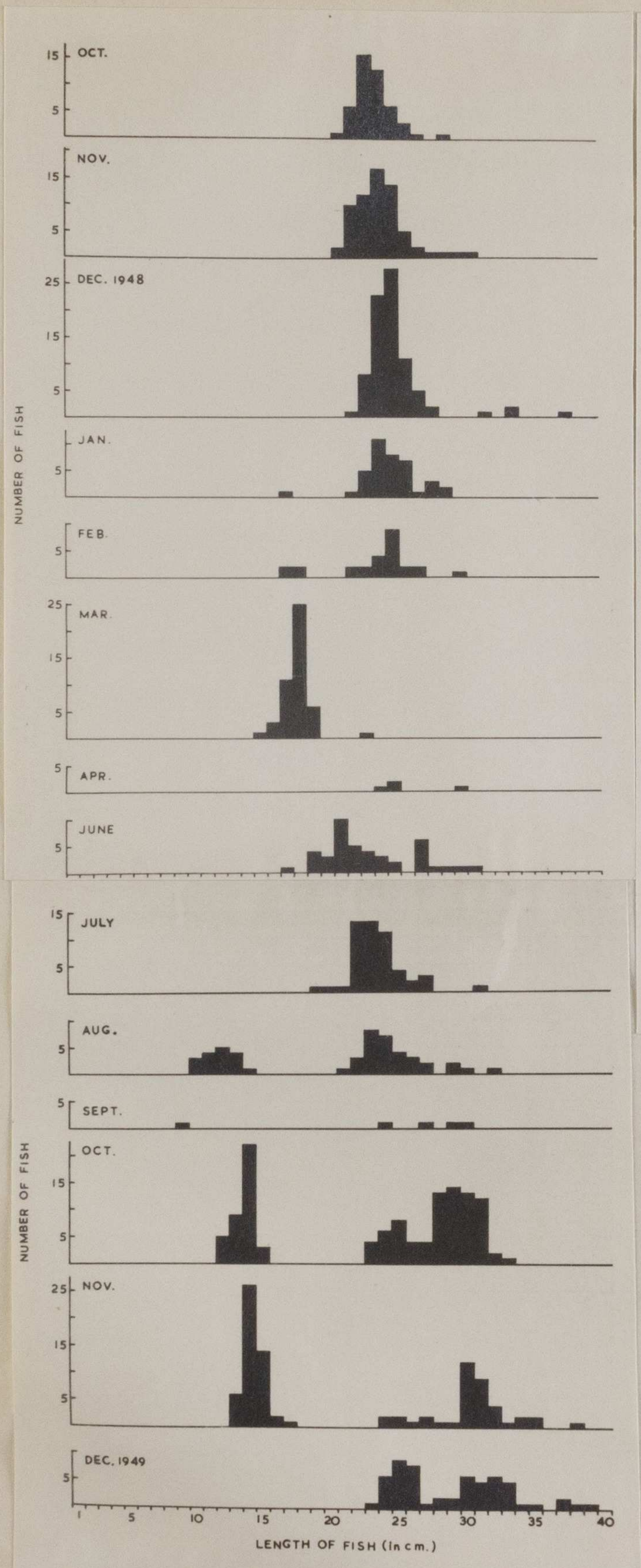
The otoliths and scales were collected in a few samples for age determination.

<u>Occurrence</u>

The coal fish (<u>Gadus virens</u>) is mainly a migrant in the Bay, the visiting period varying with the age. Day (1880) found that "in the Orkneys the fry are first seen in May ... but it is in winter when the sea begins to get stormy, that the large shoals appear ... about March they retire to the deep and grow rapidly ... few are taken in the second year ... subsequently they attain to a vast bulk ... but are rare." The first O-group individuals, measuring from 13 to 26 mm., were caught in the D-net along the bottom in the region between the life-boat slip and the inside of the breakwater in the latter weeks of May. The main shoal of the same age-group appeared close inshore from August to November. None were taken in December in the years 1948-50; few occurred in the following months. The main shoal reappeared in March and April.

Schools of second year fish occurred close to the shore in the summer of 1949, but none was obtained in the summer of 1950. The catch in the summer is not at all comparable with that in the winter when large shoals of this age group, accompanied by the third year group, moved inshore after dark or with the approach of darkness and moved offshore before dawn.

As shown in Fig. 1. the length frequency of coal fish in the successive months show the occurrence of different year groups. It agrees with Petersen's graph in the existence of the well defined modal groups. This is especially distinct among the O-group fish which are well separated from the other year groups and is traceable till the following winter. A few readings of otoliths in October samples indicate the separation of the second and the third year groups at about 30 cm. An extensive study of otolith will, probably, show an overlapping of the second and the third year groups at a certain range of the body length.



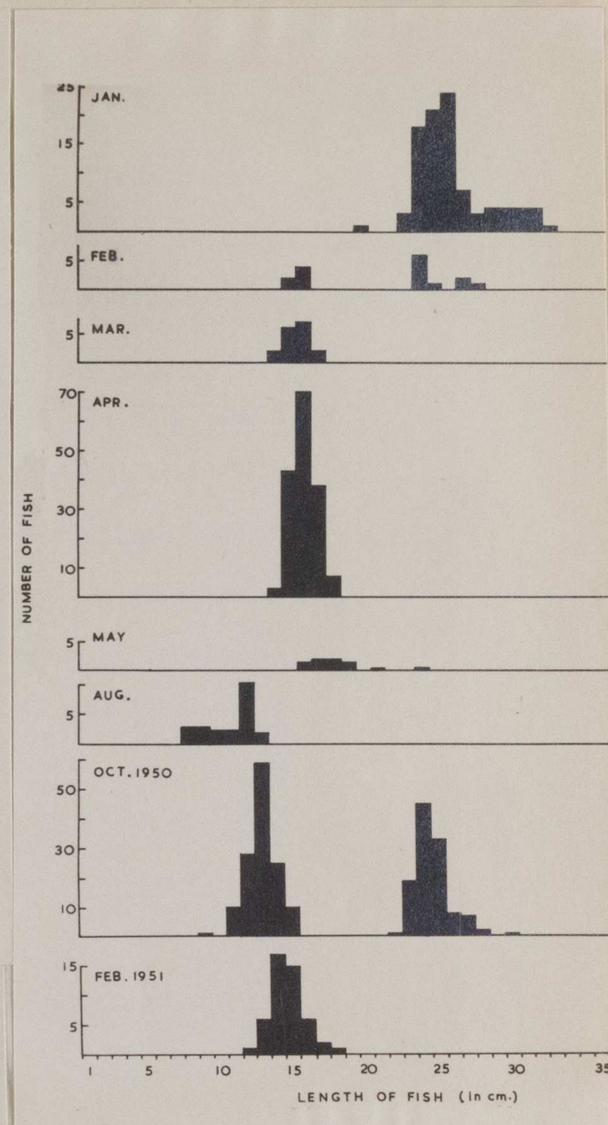


Fig. 1

The size composition (length frequency) of coal fish (Gadus virens) in Port Erin Bay during the period from October, 1948 to February, 1951.

The Weight and Length Relation

Keys (1928) proves that the equation $W = aL^3$ is an incorrect formulation of the weight-length relation, and the true relation is much more accurately depicted by the more general equation $W = a (L)^n$ (W = weight, L = length, 'a' is a constant, and 'n' expresses the rate of change of weight with length.)

The data of weight and length of the coal fish (Gadus virens) were accordingly calculated. The length was assessed into size groups in cm. with the body weight in gm. The relationship between the logarithm of the length and that of the weight is shown in Fig. 2. It will be seen that the weight-length relation is represented in a straight line. The value of 'n', based upon the calculation of any two points on the graph, is found to be 2.9.

The value of 'a', as a condition factor, has been employed broadly to measure the conditions of fishes in different environments, such as the degree of fatness (herring, Battle, 1936), to distinguish the growing period from the non-growing periods (young herring, Marshall, Nicholls and Orr, 1939) and to show the seasonal change consequent to the spawning period (hake, Hickling, 1940; and poor cod, Menon, 1950). Menon (1950) finds that the value of the condition factor decreases when both sexes attain maturity. The condition factor in the present work is computed from the data of immature young coal fish and thus the influence of breeding is not dealt with. From Table 1, it is apparent that the value of 'a' does not change with the increase in body length.

The mean value of 'a' of the monthly samples has been plotted as a curve (Fig. 3). It will be seen that the value of 'a' fluctuates: the high value being from June to August and again in November 1948 and from September to October, 1949; the low value from December to April, and again in September. The fluctuation synchronizes with the feeding activity of the fish, as shown in Fig. 5. It is apparent that the amount of food eaten is a strong determining factor on the condition of the fish.

TABLE 1. VALUE OF 'a' FOR THE INDIVIDUAL LENGTH GROUPS IN THE DIFFERENT MONTHS

cm.	No. of fish	1948 Oct.	Nov.	Dec.	1949 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Average
10	3											.02392					.02392
11	4											.02386					.02386
12	10											.02447		.02522			.02494
13	19											.02295		.02589	.02471		.02369
14	49											.02230		.02371	.02415		.02391
15	18						.02486							.02293	.02331		.02277
16	5						.02384								.02223		.02319
17	16				.02190	.02108	.02190			.02865					.02325		.02230
18	22					.02266	.02151										.02161
19	11						.02056			.02505	.02388						.02249
20	4									.02514	.02682						.02556
21	14	.02416	.02651							.02269	.02489						.02349
22	39	.02392	.02584	.02392		.02495				.02367	.02482	.02443					.02472
23	175	.02395	.02249	.02417	.02261	.02575	.02239			.02361	.02384	.02721		.02474		.02395	.02401
24	104	.02296	.02456	.02346	.02395	.02276		.02028		.02584	.02505	.02594	.02445	.02604	.02445	.02375	.02416
25	96	.02288	.02358	.02323	.02243	.02260		.01934		.02340	.02446	.02773		.02490	.02614	.02367	.02356
26	47	.02254	.02411	.02230	.02277	.02261					.02428	.02734	.02065	.02529	.02600	.02301	.02365
27	29	.02055	.02076	.02175	.02132	.02190				.02422	.02720	.02662		.02720	.02393	.02344	.02400
28	24		.02269	.02091	.02408					.02288				.02383	.02701	.01614	.02482
29	24	.02010	.02394		.02359					.02469		.02601	.02233	.02377	.02314	.02331	.02372
30	37		.01806			.02347		.02186		.02186		.02415	.02373	.02368	.02400	.02482	.02439
31	29		.02478							.02980	.02152			.02352	.02450	.02342	.02399
32	13			.02059								.02806		.02770	.02500	.02366	.02448
33	8													.02215	.02519	.02396	.02366
34	6			.02374											.02486	.02421	.02023
35	3														.02556	.02210	.02440
36																	
37	2															.02371	.02371
38	3			.02688											.02401	.02254	.02447
39	1															.02883	.02883
Mean		.02329	.02405	.02303	.02251	.02291	.02171	.02136		.02459	.02486	.02555	.02279	.02433	.02357	.02351	

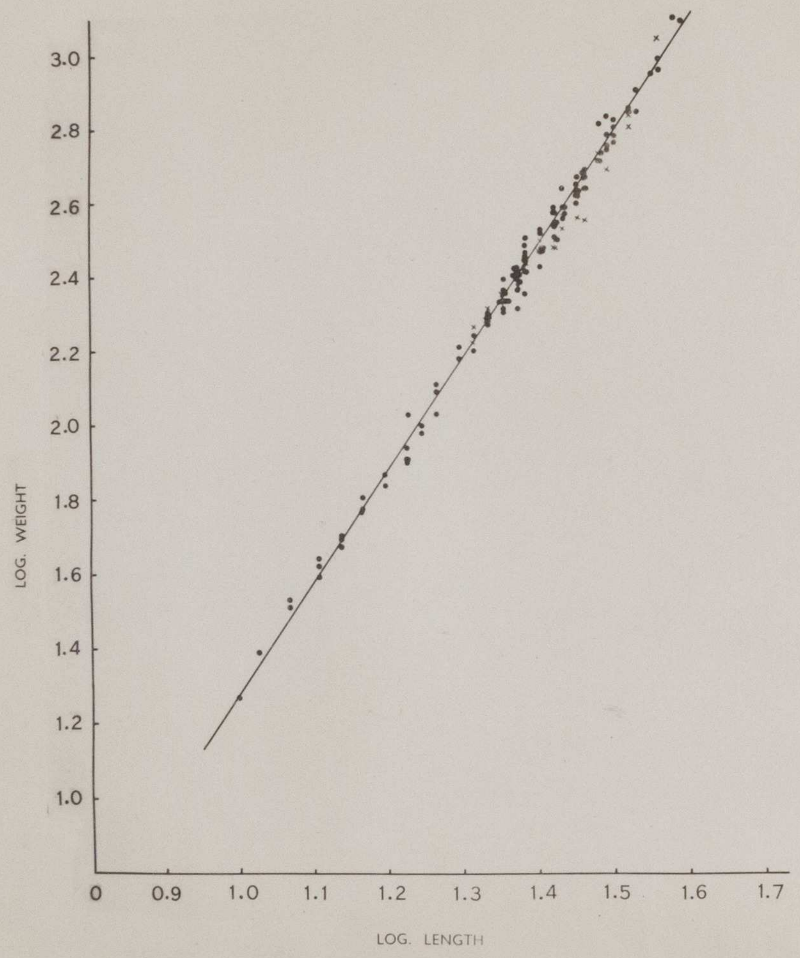


Fig. 2. Relation of logarithm of weight to logarithm of length in adolescent coal fish.

x - 1948

• - 1949

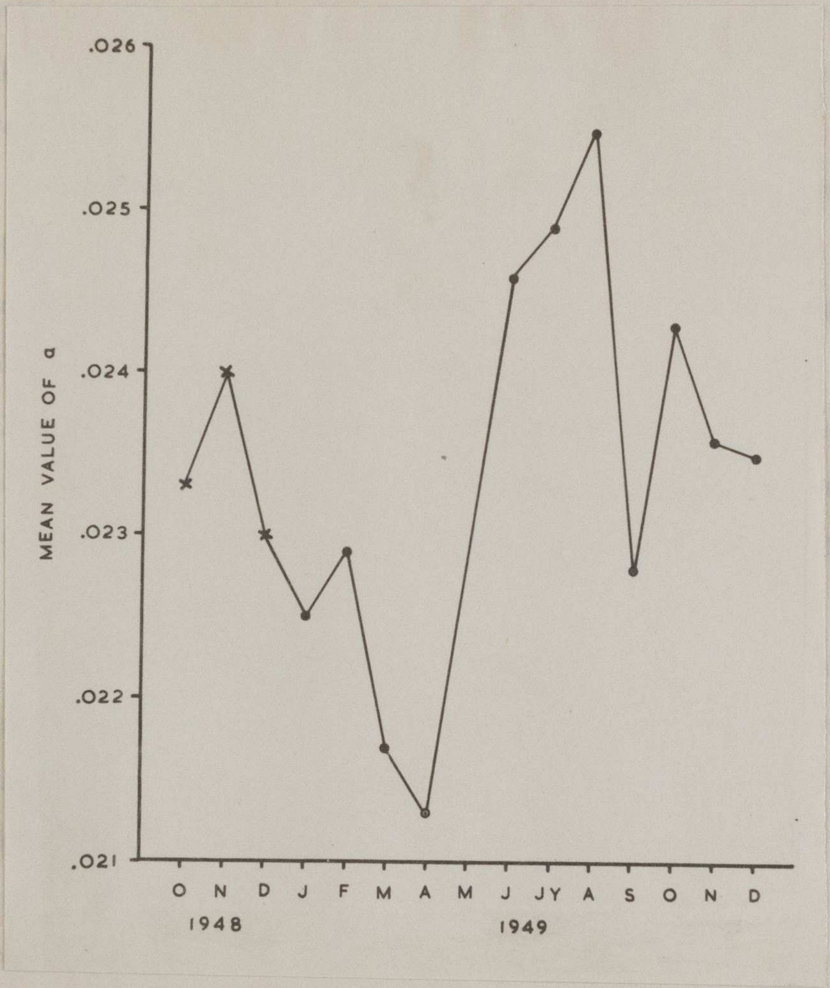


Fig. 3 The mean 'a' value for the whole samples of coal fish in successive months.

x - 1948

• - 1949

⊙ - Samples with less than 10 fishes

Damas (1909) shows the different periods of growth of the O-group coal fish in Norway: "l'accroissement rapide du début de l'été, le ralentissement estival, la reprise de la croissance pendant une courte periode d'arriere-saison, le retard automnal et la quasi-stagnation hivernale".

An attempt has been made to summarise the size frequency of coal fish during the successive months, in Table 2, by grouping the samples into quarterly totals, and calculating the mode for each age group (Table 3). In grouping the quarterly totals, all available data collected during the period 1948-1951 are included. In the figure a part of the curve is based on a hypothetical source by assuming that hatching occurs in March, and that the newly hatched larvae are 4 mm. (Ehrenbaum, 1905).

From Table 3 it is seen that the samples of the O-group individuals showed a modal length of 12.4 cm. in August ~~1949~~, when first appearing in the Bay, and reached 13.9 cm. in November. It can be assumed that the first year individuals grow rapidly after hatching, probably in March or April until November. A quiescent period follows in winter, from November to March, when these fishes reached a modal length of 15.0 cm. The rapid growth is resumed after April. Group 1 (second year fish) and group II (third year) exhibit the same features in growth (Fig. 4). Marshall, Nicholls and Orr (1939) show that there is no increase in the median length of the inshore young herring from the beginning of November to the beginning of April.

The growth of coal fish of 1949 and 1950 amounted to 18.4 and 16.1 cm. respectively at the end of the first year. Damas (1909) has shown from a series of measurements of specimens collected at various localities from Southern to Northern Norway that the increase in length during the second year amounts to 8 cm. at Lofoten, and 16 cm. in the vicinity of Risör. Obviously the O-group coal fish in Port Erin Bay grows with greater rapidity than those in Norway, and the results agree with Damas' statement that "on voit clairement que

Table 2. Length measurements of coal fish (Gadus virens).

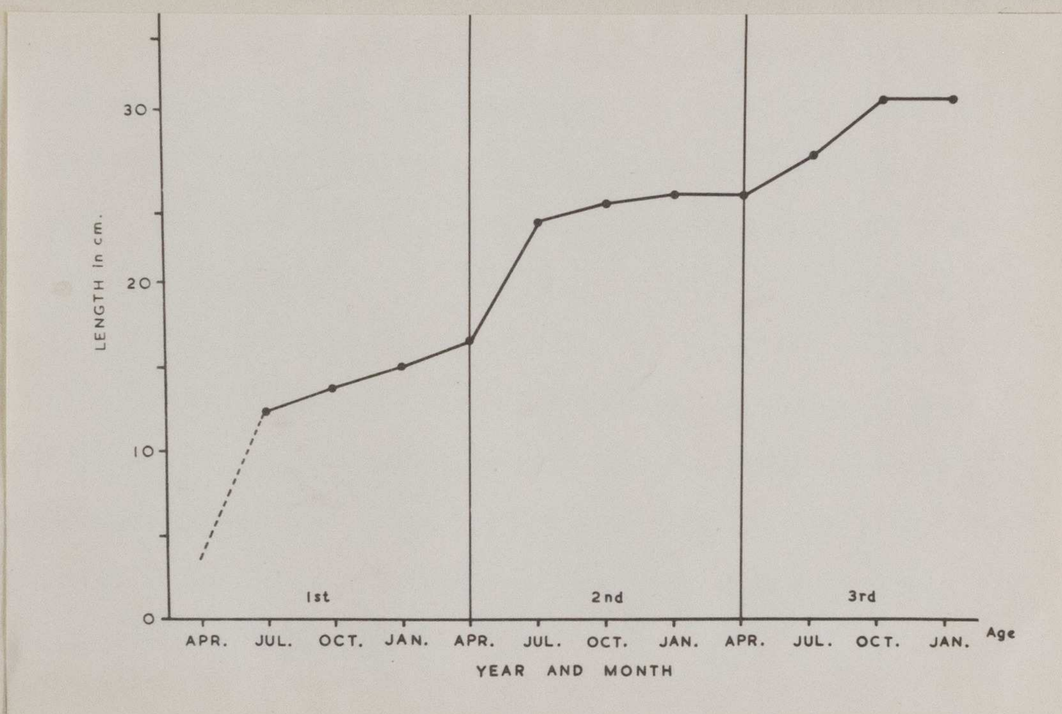
	1948			1949												1950						1951
cm.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Aug.	Oct.	Feb.
8																					6		
9												1									6	1	
10											3										5		
11											4										5	10	
12											5		5								11	28	1
13											4		9	6							4	59	6
14											1		22	26				2	3			25	17
15						1							3	14			2	6	43			10	15
16						3								2			4	7	70	3			6
17				1	2	11			1					1				2	38	4			2
18					2	20													7	4			1
19						6			4	1										3			
20									3	1						1							
21	1	2							10	1	1									1			
22	6	9	1	1	2				5	13	3											1	
23	16	13	8	5	2	1			4	13	8		4		1	3						19	
24	13	17	23	11	4		1		3	11	7	1	6	1	6	19	7			1		45	
25	6	14	28	8	9		2		2	4	4		8	2	9	19	1					33	
26	3	5	11	7	2					2	3	1	4	1	8	26						8	
27	1	2	5	1	2			No sample	6	3	2		4	2	1	7	2					7	
28		1	2	3					1				13	2	2	3	1					2	
29	1	1		2					1		2	1	14	1	1	4							
30		1			1		1		1		1	1	13	12	7	4						1	
31		1							1	1			12	9	5	4							
32			1								1		1	4	6	4							
33													2	1	5	1							
34			2										1	2	1								
35														2	1								
36																							
37														1	2								
38			1												1								
39															1								
40																							
Total	47	66	82	39	26	42	4	0	42	50	49	5	121	89	57	95	17	17	161	16	37	249	48

Table 3a Quarterly length-frequency of coal fish (Gadus virens)

Period	Mar. May	June Aug.	Sep. Nov.	Dec. Feb.
8		6		
9		6	1	
10		8		
11		9	11	
12		16	33	1
13		8	74	6
14	5	1	73	17
15	50		27	17
16	83		2	10
17	55	1	1	5
18	31			3
19	9	5		
20		4		1
21	1	12	3	
22		21	16	4
23	1	25	52	19
24	2	21	83	70
25	2	10	63	74
26		5	22	54
27		11	16	18
28		1	18	11
29		3	18	7
30	1	2	28	12
31		2	22	9
32		1	5	11
33			3	6
34			3	3
35			2	1
36			1	
37				2
38				2
39				1

Table 3b Quarterly Model length of coal fish (Gadus virens).

Quarter	Mar. May	June Aug.	Sep. Nov.	Dec. Feb.
Years of Life		Modal Length (c.m.)		
1		12.4	13.9	15.0
2	16.5	23.5	24.5	25.1
3	25.0	27.4	30.6	30.6



<u>Fig. 4.</u> <u>Gadus virens</u>.

Modal length of coal fish in each quarter from Port Erin Bay.

la taille atteinte par les divers groupes d'individus, diminue avec la latitude".

Food Species found in the Present Investigation

Plankton

Sagitta sp. An important food item in the winter months (November to February). The stomachs of a sample collected on 23.XI.48 contain nothing but Sagitta, with the greatest number of 3500 in a single stomach. The abundance of Sagitta in the stomach content fluctuates; these were abundant in the winter of 1948-49, but scarce in the corresponding period in 1949-50 when some were found only in the stomach sample of 24.X.49. It showed signs of becoming abundant again in the winter of 1950-51, as the samples obtained on 5.X.50 were found distended with it. In most cases, the Sagitta in the stomach forms a well-digested mass at the pyloric end with the most recently devoured at the cardiac end. The counting in this work is based on the newly devoured ones. The fishes which feed on Sagitta range from 180-300 mm.

Tomopteris Occurred in the same period as Sagitta. More abundant in December and January than at other periods. The number as a whole was far smaller than that of Sagitta in the stomach contents, the highest number being 65 specimens in a single fish.

Calanus finmarchicus Highly abundant in most samples from September to October. Less abundant in November and December, and few in January and February.

A shoal of coal fish was observed feeding on the surface in the harbour about noon on 24.X.49. 11 fishes were obtained by rod and line from the shoal between 1510 to 1625 hrs., and the stomach contents were found to consist almost entirely of newly ingested Calanus, ranging from 960 to 11320 individuals in a single stomach, and weighing 2.3 - 23.3 gm. The fishes measured 25 - 31 cm.

Small numbers of Calanus have been obtained from the O-group fish in April and May.

Other Copepoda

Centropages hamatus, Temora longicormis, Anomalocera patersoni, Pseudocalanus sp. occurred in the stomachs of the O-group fish in April and June; of these, Temora was the most abundant form. 645 individuals have been obtained in a single stomach. 24 Anomalocera patersoni and 2 Temora occurred in the sample of 18 fishes on 20.X.49. All the fish that feed on these Copepods are O-group and 1 year fishes.

Larvae of Decapods   Frequently found in the samples of June and July. The Larvae were mostly of zoea and metazoea stages, and as many as 173 individuals have been found in a single stomach. A few were found in a single fish, measuring 96 mm. on 1.IX.49. Fishes that feed on decapods larvae measured 21-25 cm.

Caligus rapex   Two were found in fishes, measuring 23 and 18 cm. on 23.XI.48 and 24.III.49 respectively.

Pleurobrachia   1 specimen occurred in a fish measuring 28. cm. on 18.XII.48.

Euphansiacea

Meganyctiphanes norvegica   8 coal fish collected on 23.XI.49 were distended with newly fed Meganyctiphanes norvegica and up to 213 complete individuals were found in a single stomach. Few were found in other samples obtained in December, January and February.

Mysidacea

Schistomysis spiritus   Occurred in fair numbers in all the samples throughout the year except in October and November when it is replaced by the plankton. Individuals of all sizes were present in the contents, the young forms predominating in June and July. A single stomach, collected on 23.VI.49 contained 375 individuals which, except for 41 adults, were all young forms. Usually this species does not occur in large numbers in coal fish stomachs.

Paramysis arenosa Occurred in the stomach contents of 20 fishes obtained in the months of November, December, January, February, March and July, nine being obtained in July. The highest number of 7 was recorded in a fish measuring 24 cm. on 18.VII.49 while only one or two specimens were found on other occasions.

Praunus flexuosus Occurred in 7 stomachs in August, October, November and January. 2 was the usual number of individuals in each.

Praunus inermis Only one ovigerous female was obtained in a specimen, measuring 16.cm., on 28.II.50.

Leptomysis mediterranea 97 complete and 16 partly digested specimens were found in the stomachs of 8 fishes on 8.XII.48. The highest record was 17 individuals in a single stomach. Other single records were obtained in the samples of 28.X.48 and 3.III.49.

L. linguura Found in 8 stomachs, collected in December 1948, March and October 1950. Of these three were obtained in October. 6 individuals were obtained in a single stomach in December.

Siriella armata Found in 33 stomachs in the months from October to February. 17 of these were obtained in October and 10 in December. The highest number of 15 individuals was found in a single stomach, but 2 was more usual. The coal fish that fed on this species varied from 13 to 30 cm. in length.

Siriella jaltensis Frequent in the stomach contents from September to March. The highest number of 81 individuals was found in a fish, measuring 25 cm., collected on 24.I.50, and the highest total, 101 specimens, was found in 14 fishes, measuring from 12 to 14 cm., out of a sample obtained in the Raglan harbour on 20.X.49.

Isopoda

Eurydice pulchra   Occurred in the stomach in small numbers throughout the year, except for two samples, collected on 20.X.49 and 13.IV.50 from a large shoal of young coal fishes observed feeding under the harbour light. 645 individuals were found in 18 fishes of the former sample and 163 in 25 fishes of the latter. This seems to show that Eurydice pulchra was attracted to the light and was then devoured by the fish. This species was found in fishes of all sizes from 9 to 24 cm.

Gnathia sp. Occurred in 3 stomachs collected on 2.VII.49, 20.X.49 and 28.II.50 respectively. All specimens were young forms.

Idotea baltica   Occurred in stomachs throughout the year and occasionally in great numbers in the winter months (October to December). The abundance of this species in stomachs shows distinct annual fluctuation, the number in the winter of 1948-49 being considerably higher than that in 1949-50. It is noted that 26 fishes out of a sample of 47 fishes, collected on 28.X.48 and 30.X.48, fed on this species. The frequency became low in November and December, though the highest number of 111 individuals in a single stomach was found on 21.XI.48. 129 fishes were sorted out of catches on 5, 15, 20, 21, 22 and 24 of October, 1949; of these only 3 fed on this species. One of the 3 stomachs collected on 24.X.49 contained 117 individuals of which 7 measuring 26-30 mm., 12 measuring 16-21 mm., 30 measuring 9-15 mm. and 68 measuring 5-8 mm.; two other stomachs collected on 22.X.49 contained 2 and 4 individuals respectively.

Idotea emarginata   Appeared in the stomach contents in October, November and December. 1409 individuals occurred in 39 stomachs out of 47 fishes collected on 28 and 30 October, 1949, with the highest number of 272 specimens in a single stomach. Its occurrence in the contents became sporadic in the remainder of the year, but as a whole, its occurrence was more frequent and higher in number than that of I. baltica. 4 out of 129 stomachs contained I. emarginata in October, 1950, 78 individuals having been found in a single stomach.

Idotea neglecta Few in the stomach contents as compared with I. baltica and I. emarginata. 28 individuals were found in 7 out of 47 stomachs collected on 28 and 30 October, 1948, and 10 in 7 out of 81 stomachs obtained on 12, 18 and 20 December, 1948. Few occurred in January, February and August of 1949. The highest number of 217 individuals was found in a single stomach on 3.X.49.

Idotea viridis Occurred occasionally in October, November, December, March and April. The number has never exceeded two individuals in a single stomach.

Amphipoda

Gammarus locusta Occurred in small numbers in most parts of the year. It formed an important part of the food in the winter of 1948, being abundant in the stomachs in October and December. 241 individuals were found in 33 out of 47 stomachs in October, and 178 in 25 out of 81 stomachs in December. 8 stomachs out of 129 contained 29 individuals in October, 1950, with 15 individuals in a single stomach.

Nototropis swammerdami Abundant in the stomach contents in October and November, 1948. 624 individuals occurred in 27 out of 47 stomachs in October, and 103 in 3 out of 65 stomachs in November. The highest number was 126 individuals in a single stomach collected on 28.X.48.

Melita spp. These specimens almost all belong to Melita hergensis. There was only one Melita palmata on 24.XII.48. M. hergensis occurred in the stomachs in October, November, December and March, the highest number being 3 in a stomach collected on 3.III.49.

Stenothoë monoculoides Found only twice, on 28.X.48 and 5.I.49. The former occurrence was of 3 individuals found in a fish measuring 23 cm., and the latter was 1 individual in a fish measuring 29 cm.

Pontocrates arenarius Occurred sparingly in the stomachs from December to March, and again in July. More frequent in January. The number has never exceeded 3 in a single stomach. This species has been found in fishes of all sizes ranging from 16 to 25 cm.

Pontocrates norvegicus Less frequent in the stomach contents than P. arenarius. It occurred in abundance in a small sample of 14 young coal fishes collected on 28.III.50, measuring 14-16 cm. 474 specimens were found in 10 stomachs, 3 of which contained 92-99 specimens. Other records were 3 individuals in 2 fishes, measuring 27 and 21 cm., collected on 5.I.49 and 8.VI.49.

Urothoë brevicornis Single specimens were found in 2 stomachs collected on 26.I.49 and 3.III.49; and 11 individuals in 4 fishes measuring 22-25 cm. on 23.VI.49. The highest number was 5 individuals in a single stomach.

Urothoë marina Recorded once in a fish of 27 cm. on 8.VI.49.

Haustorius arenarius Single specimens found in 2 young coal fishes, 15 and 17 cm. collected on 3.III.49

Amphithoë rubricata Occurred singly on 20.XII.48 and again on 20.X.49 in two coal fishes, measuring 23 and 12 cm. respectively.

Hippomedon denticulatus Found once in a stomach on 5.I.49.

Apherusa jurinei Found occasionally in stomachs in January, February, March and July. The highest frequency of occurrence was in 5 stomachs out of a sample of 11 fishes, collected on 25.I.49. The highest number was 9 individuals in a single stomach, collected on 28.I.49.

Apherusa bispinosa   Found in 10 stomachs in October and November, 1949. The highest number obtained was 21 individuals in a young coal fish, measuring 9 cm. Other fishes that fed on this species ranged from 13 to 34 cm.

Bathyporeia spp. Three species, B. elegans, B. guilliamsoniana, B. pelagica, were found in the food contents of coal fish. B. elegans occurred in 11 out of 25 fishes measuring 17-19 cm. collected on 3, 23, 24, 28 and 30 of March, 1949, and 106 individuals were counted in a single stomach. Other records of single or few individuals were obtained in April and July. B. guilliamsoniana occurred less commonly; three fishes, 19, 23, 24 cm. respectively collected on 2.VII.49, were found to have fed on this species. B. pelagica was found in fair numbers in a sample collected on 28.III.50. 9 out of 14 fishes, measuring 14-17 cm., were found to have fed on this species. The number of individuals found in 6 stomachs varied from 21 to 52.

Calliopius crenulatus   Recorded only twice in two fishes, 14 and 24 cm. collected on 2.VII.49 and 20.X.49.

Megaluropus agilis   Recorded once in a fish, 22 cm., on 2.VII.49.

Hyale prevosti   Single records on 18.XII.48 and 3.III.49 in two fishes, 17 and 25 cm. respectively.

Gammarellus homeri   Found in 4 stomachs in February and March 1949. 13 individuals were obtained in a young coal fish, measuring 18 cm. on 28.III.49.

Aora typica   Found singly in 4 stomachs in August, October and November. 3 of the coal fishes measured 12 to 14 cm. and one 27 cm.

Dexamine spinosa   Found in two fishes, measuring 25 and 29 cm, respectively on 22.X.49 and 12.XII.49. Two specimens were young forms of 6 and 8 mm.

Nannonyx goësi Found in a fish measuring 24 cm. on 18.VII.49.

Jassa falcata 331, 83, 32 and 7 individuals of this species were found in 4 stomachs from October to January. The fishes measured from 23 to 31 cm.

Caprella linearis Occurred in 7 stomachs, collected in October, November, and January. The maximum number in a single stomach was 1426 individuals, and the minimum 16. The fishes measured from 23 to 31 cm.

Decapoda

Carcinus maenas Found on one occasion in a fish of 23 cm. on 28.X.48. The specimen measured 6 mm. across the carapace.

Crangon vulgaris Occurred singly in 6 stomachs in June, July, August, October and January. Specimens eaten in the summer months were young forms, measuring around 30 mm. and those in January were immature forms, measuring 41 and 42 mm.

Philocheras trispinosus One or two specimens were obtained in 8 stomachs in July, November, 1949, and January, 1950. Two specimens obtained in January measured 20 and 28 mm. respectively.

Hippolyte varians 5 specimens were obtained in 4 stomachs collected in October and November.

Spirontocaris cranchi Found in one fish, 28 cm., collected on 20.X.49.

Pandalus montagui 5 specimens occurred in 4 stomachs. One was collected on 15.VII.49 and the rest on 15.X.49 and 24.X.49.

Eupagurus sp. Occurred in 2 samples, of which one obtained in a fish of 28 cm. on 5.I.49 was a Gibbula shell and was identified as E. bernhardus; the other collected in a fish of 28 cm. on 8.VIII.49 consisted of fragments of the appendages.

Cummacea Occurred rarely in the stomachs of young fish of 18 and 19 cm. in March, June and July. Complete specimens were identified as Iphinoe trispinosa.

Mollusca

Rissoa Occurred in small numbers in the stomachs throughout the year. The highest number of 153 individuals was found in a fish of 22 cm. collected on 24.VI.49. The coal fish that fed on Rissoa ranged from 14 to 31 cm., most being in the range of 22 to 26 cm.

Mytilus edulis A specimen measuring 3 mm. was found in a fish of 25 cm. collected on 20.XII.48.

Patina pellucida 8 specimens were obtained in 5 fishes, 4 measuring 25-26 cm., one 14 cm., in October, December and January.

Polychaeta

Glycera Found in stomachs of 15 fish of 17 to 28 cm. in January, March and April. These worms were partly digested, and were difficult to identify or even to count.

Nephthys 4 specimens were found in a single stomach of a young fish of 18 cm. on 23.III.49.

Arenicola Occurred in the stomachs of 3 fishes of 18-25 cm. in March and April.

Tellina fabula Occurred once in a fish of 28 cm. on 28.I.49.

Phyllodoce maculata 3 specimens were found in 2 young fishes of 17 and 18 cm. on 3.III.49.

Hydrozoa obelia Large amount found in two fishes of 27 and 24 cm. on 15.VIII.49.

Ascidiae compositae 10 specimens were found in the stomachs collected from September to November and again in January, 5 being obtained in October. The fishes measured from 14 to 32 cm.

Diptera 163 maggots found once in a fish of 19 cm. collected on 24.III.49.

Pisces

Ammodytes sp. Occurred in the stomachs in small numbers throughout the year and showed increase both in number per stomach and in frequency in June and July. Ammodytes eaten ranged from 44 to 170 mm. in body length, and the highest number was 8 individuals in a single stomach.

Clupea sprattus Occurred in the stomachs only in the latter week of July, 1949, when the coal fish fed largely on this species. The highest number in a single stomach was 42. The fishes ranged from 20-27 cm.

Gobius sp. Found in 11 stomachs from October 1949 to January 1950. The 7 specimens collected in January were identified as G. jeffreysi. The fishes ranged from 22-31 cm. except for one of 14 cm. collected on 7.XI.49.

Comparison of Food of Coal Fish of Different Sizes

A most striking fact which emerges from the study of the food of the inshore feeding coal fish (*Gadus virens*) is the feeding on plankton by adolescent fishes, especially in October and November. This prolonged period of planktonic feeding in *Gadus virens* marks its difference from the other gadoids which feed on the plankton only during their post-larval stages (Lebour, 1918, 1919; Menon, 1950). The inshore coal fish is almost exclusively a pelagic feeder, feeding mainly on crustacea and the small fishes which swim close to the surface layer of the water and on bottom-living forms when these are pelagic at certain periods of the year. Benthic forms are hardly eaten at all by coal fish.

Table 4 shows that the diet of the first year coal fish differs slightly from the other age groups in including a number of small food organisms, such as *Temora*, *Pseudocalanus*, *Calanus*, *Siriella jaltensis*, *Eurydice pulchra*, some small Amphipods, especially *Bathyporeia pelagica* and *Pontocrates norvegicus*, and occasionally young *Ammodytes* and *Gobius*. The diet of the second and third year fishes is of greater variety and the food animals are comparatively large. *Temora* and *Pseudocalanus* are replaced by *Tomopteris* and *Sagitta*, and together with *Calanus*, *Idotea*, *Gammarus* and *Ammodytes*, constitute the main diet. *Schistomysis spiritus* is of equal importance to all age groups.

Nordgaard (1901) noted that the first year coal fish is satisfied with planktonic food, and when the plankton becomes scarce resorts to seaweed to feed on Amphipods, Isopods, Ostracods and Molluscs, and even Hydroids. The present studies show little evidence of the first year coal fish feeding in seaweed. However, it is noted that these fish feed at this period mainly on *Schistomysis spiritus*, *Bathyporeia* and *Pontocrates* and young Idoteids and Gammarids which swim in the intertidal region. The second and the third year fish seem to feed more frequently in the seaweed in winter as shown by

TABLE 4 FOOD OF COAL FISH (*Gadus virens*)

Date	Age group of fish	No. of fish	No. of empty stomachs	*Calanus finmarchicus*	*Tomopteris* sp.	*Sagitta* sp.	Other copepod plankton	*Meganyctiphanes novegica*	*Schistomysis spiritus*	Other mysids	Mysids fragments	*Eurydice pulchra*	*Idotea baltica*	*I. emarginata*	Other *Idotea*	*Idotea* fragments	*Pontocrates arenarius*	*P. norvegicus*	*Gammarus locusta*	*Nototropis swammerdami*	*Jassa* sp.	*Caprella* sp.	Other amphipods	*Crangon vulgaris*	Other decapoda Natantia	Other decapods	*Rissoa* sp.	Other molluscs	Polychaetes	*Ammodytes* sp.	*Gobius* sp.	*Clupea sprattus*
				No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
1948																																
Oct.	>1	0																														
	<1	47	8	207			1		431	5	559	3	217	1465	31	284			448	763	332	79	5			2	48			5		
Nov.	>1	0																														
	<1	66	33	806	273	21885			33	4	102		132	348	11	189			162	307	3	25										
Dec.	>1	0																														
	<1	82	23						206	106	75		26	342	23	117	1		257	45			4				20	2				
1949																																
Jan.	>1	1	0						14		13								1													
	<1	38	2		65	76			292	16	177			60	1	11			52	9	146	16	9				73		2	2	14	
Feb.	>1	4	0	6	5	66			134	2				13		2			2	5												
	<1	22	0	16	248	3244		1	66		64		15	48		3	2		19	14			13				11					
Mar.	>1	41	2			163			634	20	744	27	1	17	5	8	8	189	19	37			32			16	35		28	5		
	<1	1	0						9			3		3		6			1		1		4						5			
April	>1	0																														
	<1	4	0						14																				4			
May	No sample														No. sample																	
June	>1	0																														
	<1	42	3	2			67		646		50	26		2	4			160	3	1			14	1			173	1		57		
July	>1	0																														
	<1	50	5				307		1105	19	1209	22	3	3				7	11	29			9	3	5		5			15		78
Aug.	>1	16	0	303			676											34	1													
	<1	32	0						32	1	8		9	6	14				33	8				1	1	1				4		
Sept.	>1	1	0				11			2		6								7						21						
	<1	4	3						8		3																					
Oct.	>1	39	1	9394			24		58	47	19	619							2	13			4			2		1				
	<1	82	34	50603	263	1108			106	34	153		108	88	217	17			63	95			9	1	44		212			4	4	
Nov.	>1	49	6						140	28	70	1							3				5			1					2	
	<1	40	28					736		1	56		23	6					1	8	266	127					1					
Dec.	>1	0																														
	<1	57	32						248					1					1	3	252	141					34	4				
1950																																
Jan.	>1	0																														
	<1	95	34						1356	93	442	1	4	7	5		3		10					2		2	4	7		15		
Feb.	>1	6	3						283	2	46	3	2		1		1		8											1		
	<1	11	6						17				8	15	5				7	1												
Mar.	>1	17	3						59		4	10	3				484	207					1									
	<1	0																														
April	>1	0																														
	<1	62	1	4			5615		2			168		10			5	1	30	4			16									
May	>1	0																														
	<1	16	4	53			64		92			30						3														
Aug.	>1	30	3	679					899	1																	92			49	1	
	<1	0																														

the presence of large numbers of Rissoa, Jassa, Caprella, Hydroids, and compound Ascidians in some stomachs.

Allen (1935) has shown that perch pass through three feeding stages, plankton-feeding, bottom-feeding, and fish-feeding, during their life, and that larger fishes tend to feed on larger size food species. Coal fish, unlike perch, grow to a large size in the third year but never miss any chance to feed on small sized animals. The three types of food, plankton, mysids, amphipods, isopods, and fish, frequently occur in the same stomach, regardless of the age group of the fish.

Seasonal Variation in Stomach Contents

The composition of the stomach contents of coal fish varies with the season; certain food species alternate in importance throughout the year: plankton or Idotea, Gammarus and Nototropis in the winter (October to December): a mixed diet of mysids, amphipods, polychaetes and fish in spring (March to May) and mainly of fish in summer (June and July). However, Schistomysis spiritus is important in most months of the year.

As shown in Table 4, Schistomysis, Idotea, Gammarus and Nototropis formed the main constituents of the stomachs in October, 1948. In November these decreased markedly and the bulk was replaced by Sagitta and small numbers of Calanus and Tomopteris. During late winter and early spring when food is relatively scarce, some numbers of Jassa, Caprella, Rissoa and even hydroids and compound ascidians are found in some stomachs. The fish diet, mainly of Ammodytes, occurs in April, June, July and August. Clupea sprattus is found in the latter part of July; though the fish is not prominent in number as compared with Crustacea, it then dominates both in size and weight. Hickling (1927) remarks that G. virens feeds on one year group blue whiting (Gadus poutassou) in the deep water (100 fathom contour) off the west coast of Ireland in early summer.

The food shows annual fluctuation; certain food species may be dominant in one year but become less important in the corresponding period of the following year. In 1948 Idotea emarginata, I. baltica, Gammarus locusta and Nototropis swammerdami were abundant in the stomach contents in October, and Sagitta in November, but these were rare in the corresponding periods of 1949. Calanus were few in October of 1948, but became extremely abundant in 1949; 2 samples of 32 fishes collected on 21 and 24.X.49 were found to have fed exclusively on Calanus, one stomach in the latter sample containing 11320 newly ingested individuals. Nordgaard (1901) shows similar results in Norway; he counted 6250 medium sized specimens of Calanus firmarchicus, Centropages typicus and Anomalocera patersoni in a single stomach on 18.X.1900.

It is clear that the seasonal variations of the diet of the coal fish correspond with the seasonal abundance of the various food species in the feeding ground. The stomach content also shows the availability of certain food sources. Since G. virens is not a bottom feeder, the food source is confined to those animals which are planktonic or actively swimming; the actual bottom-living forms constitute little of the stomach contents. This is substantiated by the rarity of crustacea such as Praunus inermis, Hippolyte varians, Pandalus montagui, and Dexamine spinosa which are abundant during the summer months in the inshore water. It is also noted that Idotea emarginata, I. baltica, Gammarus locusta and Nototropis swammerdami predominate in the food contents when they perform their winter swarming, moving from the shallow water to the water's edge.

Fig. 5 shows the average weight of the stomach contents in each month. The feeding activity as shown in the graph can roughly be divided into four periods throughout the year: (i) low feeding period in late winter and spring (January to April), (ii) maximum feeding period in June and July, (iii) a temporarily intense feeding period in autumn (October to November in 1948, and October in 1949) and (iv) a minimum feeding period in December. It is further substantiated by the relative percentage of the empty stomachs as well as the fullness of the stomachs in each month, as shown in Fig. 6.

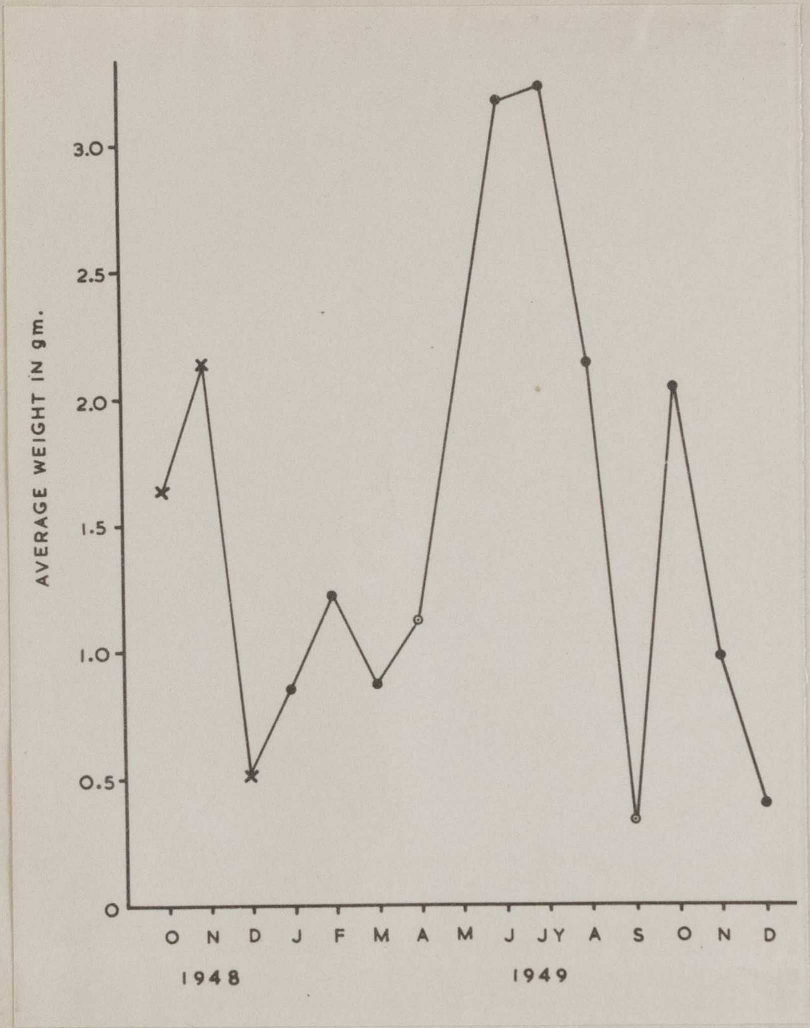


Fig. 5. Stomach contents of coal fish (Gadus virens).
The average weight in gm. of all stomachs per month
during the period from October 1948 to December 1949.

x - 1948

• - 1949

⊙ - samples less than 10 fishes

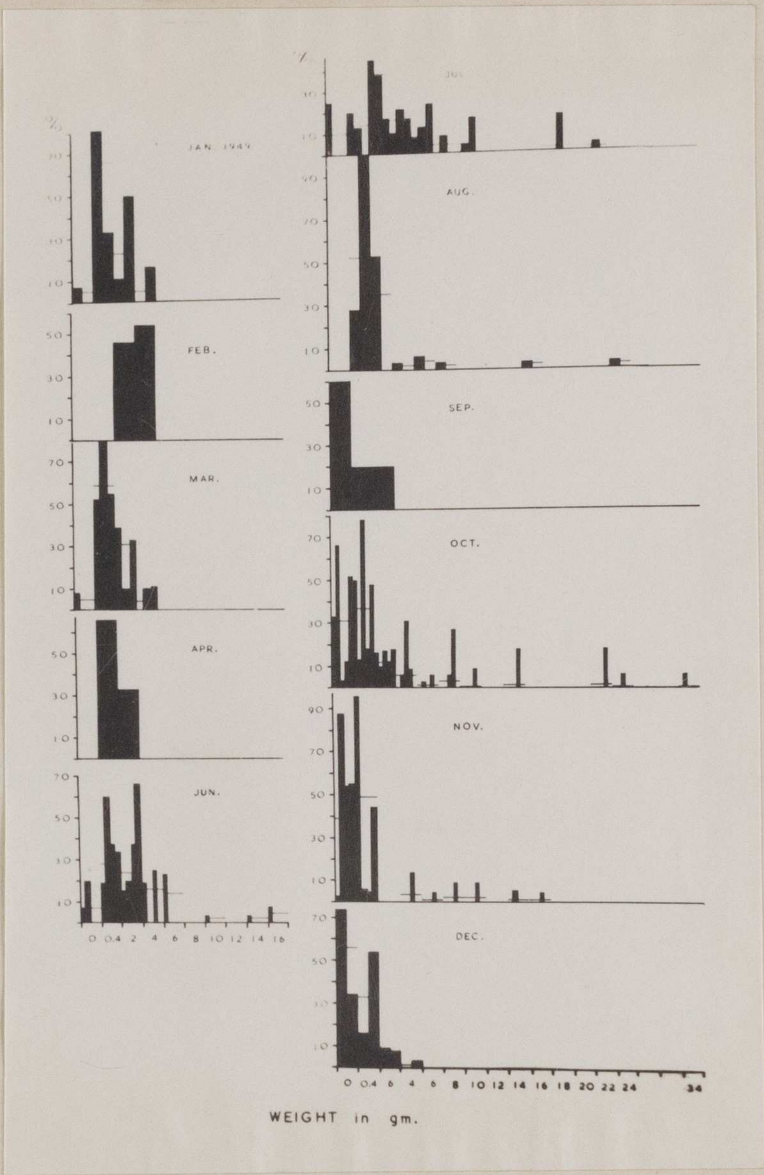


Fig. 6 Gadus virens

Fullness of stomach during successive months (except May) in 1949.

Small blocks - separate catches.

Line in the blocks - average percentage.

It is noted that there is (i) a general increase in the weight of the stomach content in a range from 0.2 to 7 gm. in June and 0.2 to 11 gm. in July. The percentage of the empty stomachs in these months (7% and 10%) does not show any prominent decrease as compared with that of the earlier months, (ii) an abrupt increase in the weight of some of the stomachs in November 1948 and October 1949, as indicated by the maximum weight of the stomach contents in each year (24 gm. on 23.XI.48, and 34 gm. on 22.X.49) and a marked increase of empty stomachs (39% & 50% in 1948 and 1949 respectively), (iii) a general decrease in the weight of the stomach contents in December and the following spring, most stomachs retaining little (0.2 to 1 gm.) food and the percentage of empty stomachs varying from 20 to 55% of the population.

Menon (1950), by plotting the average volume (c.c.) of food against the respective month, shows that there are three phases of feeding activity in poor cod (Gadus minutus) at Plymouth: (1) active feeding period, from April to July, (2) average feeding period from August to December, and (3) low feeding period from the latter part of December to the early part of March. He finds that the feeding activity is closely related with the breeding cycle in that the active and the low feeding periods synchronise respectively with the end of and the period prior to the spawning. This correlation, that the feeding activity becomes low with the approach of the spawning period and becomes intense again after spawning, has been observed in other fishes: silver eel (Patersen, 1896); plaice, dab, flounder and sole (Todd, 1907); herring (Hardy, 1924); hake (Hickling, 1927); and stickle-back (Hynes, 1950).

The material involved in the present work is composed entirely of immature fishes. The intensity of feeding is thus presumed to be uninfluenced by the breeding cycle and depending mainly on the abundance of available food. The low temperature in the winter might be another reason for the low feeding activity; it reduces both the activity of the fish and the rate of metabolism. Battle

(1936) however finds that herrings are still able to feed when the water temperature falls to 0.75°C in February. Johnson (1939) finds that herrings are less active and are not seen to feed at 3.8° - 4.5°C. The latter author, however, attributes the failure of the fish to feed at 3.8°C in his experiments to "the rate of fall of temperature being considerably greater than usually occurs in nature."

Volume of Stomach Content Correlated with Volume of Fish

The relation between the body weight and the stomach weight was studied by comparing the data of individuals assessed into size groups with regard to the approximate age, and the results are given in Table 5. The relation is the average weight of the stomach contents in mg. to each gram of body weight.

The average weight of the stomach contents was taken (i) excluding empty stomachs, and (ii) with these included, and the results are shown in Table 5. From the Table it is clear that the number of empty stomachs in a population increases steadily with the age. In the first year group nearly all the individuals contained some amount of food in October and November; the percentage of empty stomachs was rather low (0% to 14.2%). In the third year group, the percentage of empty stomachs based on the calculation of the samples of 30-43 individuals in the winter months (October-December) of 1949, varies from 46.5 to 75%. The ratio of the weight of stomach contents to body weight when a higher number of empty stomachs is included will be lower than that obtained with a less number; the empty stomachs are therefore excluded from the calculation. The results, as shown in the Table, are not directly comparable among different age groups, owing to the great difference in the number of individuals in most of the samples. The present work, then, attempts to provide no more than a general idea on the change of value between the active

Table 5. Comparison of body weight (gm.) and stomach contents (mg.) of coal fish (*Gadus virens*).

Age group	I							II							III						
Size range (cm.)	9 - 19							20 - 28							29 - 38						
Date	No. of fish	No. of empty stomachs	Average body wt. (gm.)	Average wt. of stomach contents (mg.) (excluding empty stomachs)	(1)	Average wt. of stomach contents (mg) (including empty stomachs)	(2)	No. of fish	No. of empty stomachs	Average body wt. (gm.)	Average wt. of stomach contents (mg) (excluding empty stomachs)	(1)	Average wt. of stomach contents (mg) (including empty stomachs)	(2)	No. of fish	No. of empty stomachs	Average body wt. (gm.)	Average wt. of stomach contents (mg.) (excluding empty stomachs)	(1)	Average wt. of stomach contents (mg.) (including empty stomachs)	(2)
1948																					
Oct.								47	8	204	1735	8.5	1433	7							
Nov.								61	32	245	4647	19	2301	9.4	5	1	424	4250	10	2833	6.6
Dec.								78	20	226	740	3.2	550	2.4	4	3	703	2400	3.4	600	0.8
1949																					
Jan.	1	0	81	280	3.4			35	2	252	842	3.3	795	3.1	2	0	414	325	.78		
Feb.	4	0	89	767	8.6			21	0	251	1333	5.3			1	0	451	200	.44		
Mar.	41	2	93	906	9.7	861	9.2	1	0	199	1980	9.9									
Apr.								4	0	214	813	3.7									
June								40	3	209	3340	15.9	3083	14.7	2	2					
July								49	5	232	3950	17	3515	15.1	1	0	445	2750	6.1		
Aug.	16	0	36	429	11.9			28	0	321	2204	6.8			4	0	505	8450	16.7		
Sept.	1	0	13	350	26.9			2	2	254					2	1	422	1350	3.2		
Oct.	39	1	48	667	13.8	650	13.5	39	15	320	4717	14.7	2902	9	43	19	465	5269	11.3	2941	6.3
Nov.	49	6	55	230	4.2	201	3.6	8	4	315	5150	16.3	2599	8.2	32	24	545	7996	14.6	2999	5.5
Dec.								27	11	276	768	2.7	455	1.6	30	21	586	780	1.3	234	0.4
1950																					
Jan.								78	24	258	712	2.7	490	1.9	17	10	457	1322	2.8	544	1.1
Feb.	6	3	61	1313	21.5	656	10.7	11	6	264	1352	5.1	541	2							
Mar.	17	3	59	367	6.2	302	5.1														
Apr.	62	1	64	347	5.4	341	5.3														
May								16	4	84	1178	14.0	841	10.0							

(1) Unit weight (mg.) of stomach contents to unit of body weight (gm.) excluding the empty stomachs.

(2) Unit weight (mg.) of stomach contents to unit of body weight (gm.) including the empty stomachs.

and the low feeding period in the year. The results show that (i) the first year group tends to maintain a fairly high ratio from 4.2 to 13.8 in the months of August, October and November, and with an average ratio of 7.3 from February to April, (ii) the second year group tends to show a high ratio of 8.5 to 19.0 in June, July, October and November, and an average ratio of 3.2 in the months from December to April, and 5.1 from February to April, (iii) the third year group shows the same tendency as the second year group, but the ratio in winter is lower, at a range of .44 to 3.4.

These tendencies are emphasized when the empty stomachs are included (Table 5).

It is apparent from the comparative studies that the first year fish tend to maintain a higher ratio than the second year group in early spring. Data show that in the stomach contents of the first year fish, there is a high percentage of *Schistomysis spiritus*, with some numbers of *Eurydice pulchra*, *Bathyporeia*, young *Gammarus* and *Idotea*. Obviously this group of fish are able to feed on these animals close to the water's edge where the water is too shallow for the second year group to approach. The third year group fish were obtained only from December to February and thus their ratio is not comparable with that of the first year group.

Intensity of Feeding Correlated with Light Conditions

Since the coal fish is a visual feeder light is an important factor in its feeding activity.

Daylight No sample of the second and the third year coal fish has been obtained by seine-netting in the daytime; the material was obtained by angling near the Pier. These age groups are occasionally observed feeding close to the shore during daytime in the summer months. A small shoal was observed with a large shoal of mackerel (*Scomber scomber*) preying on young sprats on 23.VII.49. 6 were caught by "Mackerel spinner" and the stomachs were found distended with sprats mixed with a few Schistomysis spiritus and decapod larvae in the metazoea stage. These groups are often observed foraging in the harbour at the end of October. 16 specimens measuring 23-30 cm. were caught from a scattered shoal between 14:10 and 16:00 on 22.X.49 on hooks baited with soft parts of Pecten maximus and Cancer fragments. The fishes were found to have fed on Schistomysis spiritus, Siriella armata, Praunus flexuosus, Leptomysis linguura, Idotea baltica, I. emarginata, Gammarus locusta, Dexamine spinosa, Apherusa bispinosa, Pandalus montagui, Hippolyte varians, Rissoa, Ammodytes, Gobius, and large amounts of fish fragments. These food species were found in fresh condition with the exception of Pandalus and the fish fragments; these latter were well digested. It seems that these fishes had been hunting in the shallow water before coming to the Pier. Another small shoal of nearly 50 individuals were seen cruising inside the Pier, about noon on 24.X.49. These fishes invariably pounced excitedly beneath a patch of detached fucoid seaweed loosely floating within the shadow of the Pier. The shoal swam towards the Pier after a few minutes of feeding and swam back again to resume feeding at the same spot. 11 specimens measuring 24-31 cm. were obtained by angling from 15:10 to 16:00 hrs. The stomachs were found distended almost exclusively with freshly eaten Calanus, as many as 11320 individuals being counted in a single stomach with a small number of Sagitta, Tomopteris, and Rissoa. The only exception was a stomach that contained a mixed diet of 3600 Calanus, 105 Idotea baltica, 78 I. emarginata, 91 Nototropis swammerdami, 51 Gammarus locusta and a small number of mysids. A sample was collected on the same date immediately after dark by seine-netting between 20:00 and 21:00 hrs. A sub-sample of 19 individuals measuring 24-34 cm., were sorted at random from a big catch. The stomachs of these fishes were found to contain less than 200 mg. of food, 3 stomachs containing a small amount of well digested Sagitta and Tomopteris, and few Schistomysis spiritus, Siriella armata and Rissoa. Apparently those fishes caught in the daytime came into the harbour mainly after Calanus.

The first year young coal fishes were often observed swimming in shoals in the harbour during the daytime in October and November. The fishes swim in compact shoals and show little sign of feeding. It is more likely that this age group shoal swims into the harbour in the daytime because of stormy weather and in the presence of the predatory shags and cormorants.

Night   The materials in the present work were obtained almost exclusively after dark. The negative results of the shore seining in the daytime led to the belief that the shoal moves close to the water's edge with the approach of darkness. It is therefore desirable to find out whether the coal fish feed after dark. Experiments have been attempted to observe the feeding activity in the dark of tame coal fishes (i.e. fish which have been kept for some time in the aquaria). Equal numbers of tame coal fishes of the first year group were starved for 2 weeks and then introduced into 2 cement tanks of identical size (2 x .8 x .6 m) two days before the experiment began. These tanks were circulated with fresh sea water. One tank was left in the dark while the other served as a control and was illuminated with a 60 watt bulb hanging 20 cm. above the water surface. Both tanks were provided with large numbers of living crustacea obtained by wading along the water's edge. The water of both was drained after 3 hrs; the stomach contents were examined and the results were shown in Table.

Date & Time	No.of Fish	No.of Empty Stomachs	Size Range (mm.)	Light Conditions	Schistomysis spiritus	Pontocrates arenarius	Gammarus locusta	Idotea sp.	Nototropis swammerdami	Ammodytes sp.
Jan. 8th 1950	8	0	190-230	Starlight	121	8	1	1	1	0
		Average -			15.1	1				
1930-2245 hrs.	8	4	190-230	Artificial light 60 watt bulb	511	10	1	0	0	2
		Average -			63.8	1.2				

It is evident that the coal fishes are able to feed in the dark though the average number of food organisms eaten was lower than that eaten under light. The fishes feeding under illumination show equal number of stomachs with and without food. The cause of the empty stomachs is not understood; it is possible that some fishes dislike the strong light, possibly the swinging of the lamp in the wind scared some of the fishes, or probably some of the species remain on the bottom at the light intensities of the experiments.

The observation was repeated with one of the groups fed 4 hours earlier with boiled mussels and both tanks covered with thick canvas to ensure complete darkness. Larger number of living food organisms was put in the tanks as compared with the previous experiment. Both tanks were drained after 3 hours and the stomach contents were as follows:

Date & Time	No.of Fish	No.of Empty Stom-achs	Size range (mm.)	Light cond-itions	Wt.of boiled mussel in stom-ach con-tents (mg)	Schistom-ysis sp.	Other mysids	Gammar-us loc-usta	Idotea sp.	Noto-tropis swamm-erdami
Jan. 14 1950	7	0	185-230	Dark	0-6900	411	0	10	7	5
			Average -		3000	58.7		1.4	1	.7
1930-2245 hrs.	7	0	188-240	Dark	0	676	3	8	42	29
			Average -		0	96.5		1.1	6	4.1

It is apparent that all coal fish feed in the pitch dark even though some have been partly fed and presumably are not desperate for food.

<u>Feeding under Light at Night</u> The O-group fishes have frequently been seen moving into the harbour in large shoals at night with the flowing tide and feeding under the harbour light. These fishes kept in compact shoals and were at first extremely shy and ready to scatter at the presence of a moving shadow or any other disturbance. But once they started to feed close to the surface, they showed little sign of being

easily frightened. This is shown when a fine mesh seine net was operated. The fishes scattered but gathered almost immediately to the surface again after the sweeping of the net.

Analysis of the stomach contents, obtained at successive hauls after the shoal moved into the harbour, leads to the belief that these fishes prefer to feed in the weak artificial light. Two samples were obtained on two successive night: the second sample was obtained immediately after the fish started to feed under the light; the sample of the previous night was obtained at the same locality but $1\frac{1}{2}$ hours later. The result of the analysis is shown in the Table.

Sample	Date	Time (min.)	No. of fish	Size range (cm.)	Calanus sp.	Anomalocera sp.	Schistomysis spiritus	Siriella armata	S. jaltensis	Leptomysis linguura	Eurydice pulchra	Nototropis swammerdami	Other amphipods	Time of feeding in artificial light
I	20.X.49	2300	18	12-14	2313	24	6	8	99	0	645	11	4	1.5
	Average				128.5	1.3	.3	.4	5.5	0	35.8	0.6	0.2	
2	21.X.49	2130	21	13-15	8076	0	59	5	0	2	13	2	5	.5
	Average				384.5	0	2.8	.2	0	.09	0.6	.09	0.2	

The two samples show similar basic contents of <u>Calanus</u>, <u>Schistomysis spiritus</u> and <u>Siriella armata</u>. The first sample shows a larger number of <u>Eurydice pulchra</u> and <u>Siriella jaltensis</u>. It is possible that both <u>Eurydice pulchra</u> and <u>Siriella jaltensis</u> were attracted to the water surface by the light and thus provided a food source for the young coal fish.

<u>Moonlight night</u> A night haul was obtained on a moonlight night at 2200 hours on 23.XI.48. The stomachs of this sample were distended with large numbers of <u>Sagitta</u> and small numbers of <u>Calanus</u> and <u>Tomopteris</u>. It was suspected that these fishes fed on these organisms by moonlight. For further proof, another sample was obtained in similar conditions at 2000 hours on 7.XI.49, but the stomach contents revealed instead only a small amount of <u>Siriella jaltensis</u> and small amphipods. Judging by the presence of the night migrant, <u>S. jaltensis</u>, it seems that the fish feed on this species in the moonlight. However this does not necessarily mean that the fishes of the first sample must have fed on <u>Sagitta</u> and other plankton under the same conditions. A better explanation seems possible when the diurnal move-

ment of these planktonic organisms is taken into consideration, in that they descend in the daytime and ascend to the surface by dusk (~~Gough, 1905~~; Michael, 1911; Easterly, 1922; Russell, 1925-28, and others). Since moonlight shows a negative influence on the diurnal movements of such plankton it seems more probable that the coal fish feeds on Sagitta, Calanus and Tomopteris at dusk when these species move to the surface in great abundance.

Johnson (1939, 1942) states that "bright moonlight is of sufficient intensity to enable the herring to feed". His method "was tested directly by exposing the fish to natural light. About 20 herrings (14-18 cm.) were kept in a wooden insolated tank (15 cm. long, 1 m. wide and 1 m. deep.) The standard procedure used under all light intensities was to drop chopped Meganyctiphanes into the tank continually for a period of 20 minutes and then remove 5 fish in order to determine whether or not food had been eaten". Johnson's method was apparently inadequate to draw any conclusion on the powers of vision of herring under moonlight, in an experiment of 20 minutes by offering the fish chopped food morsels. He also neglected to state whether or not the fish were starved before the experiment, or the condition of the moon. Moreover, he had not produced the results of the analysis of the stomach contents but merely states: "these outdoor observations thus agree with the results of experiments made with artificial light" (Battle, 1936).

Port St. Mary

Certain samples obtained from Port St. Mary were limited to small numbers of individuals measuring from 104 to 237 mm. in June and August. Analysis of these stomachs reflected that Bathyporeia pelagica was a common food species. The stomachs obtained on 13.VI.49 contained 25-98 individuals of Scolelepis fuliginosa which has not been recorded in the diet of Port Erin samples. It is thus possible that the difference in the feeding habit of the coal fish depends mainly on local conditions.

Relative Frequency of other Inshore Feeding Fishes than Gadus Virens

Other fish caught in the same net as G. virens were also studied "in order to understand the qualitative and quantitative connection between fishes and their food organisms". (Nikolsky, 1945).

Clupea harengus Linné This species occurs in the samples from March to June, the bulk being obtained in April and May. Drift nets were shot in the evening by local fishermen in the shallow water of the Bay and hauled up in the early morning. The catches were usually greater than those obtained with the seine net. This seems to suggest that the shoals keep off shore rather than moving close to the shore. The visit of herring to the shallow water seems to be an extension of the shoreward migration after the spawning period (Smith, 1948).

Gadus merlangus Linné This species provided only young individuals in the months from February to October. The visitors from July to October are largely O-group individuals, measuring 60-130 mm. These occur in large numbers in the same net with other young Gadoids, G. virens, G. callarias, and the adult G. minutus. The number in the catch decreases markedly as the size increases in the early months of the following spring and summer.

Gadus pollachius Linné This species occurs in small numbers in the seine-net samples from April to June. Some individuals have been obtained early in March and late in September. It is common in the rocky region of the bay, and small numbers have often been obtained by angling or by drift net in summer. Those individuals obtained in the bay were of similar size range, 207-293 mm., except for one measuring 150 mm. caught on 19.V.50. One was obtained in the D-net and measured 38 mm.

G. callarias Linné This species is scanty in the samples. The only exception was a large sample of young individuals, measuring 63-115 mm. on 15.VIII.50.

G. luscus Linné Rare. A few specimens have been obtained from January to May. Females were distended with ovaries in February.

G. minutus Linné This species occurs in large numbers in May, June and July, few specimens having been obtained from February to April. The individuals obtained in April were distended with gonads and those of the later months were spent individuals. Evidently, the inshore visiting is prior to and after the spawning period. The spawning period of this species at Plymouth lasts from February to May (Menon, 1950). Similar extent of spawning period of poor cod might occur in the Irish Sea.

Salmo trutta Linné This species seems to move to inshore water after dark throughout the year, but appears to be more common in the summer months. The body length of the fish ranged from 29 to 38 cm. As judged by the body length in reference to Jones' (1950) report on the scale reading of Manx sea trout, the minimum sizes of trouts "have spent only two to five months in the sea since they left the river as smolts", and the maximum sized trouts"have spent one complete year and part of a second summer in the sea before returning to the river".

Pleuronectes platessa Linné This species is fairly common in the bay, especially the newly hatched young individuals which appear very close to the shore in July. The body length of the fish ranged from 4 to 19 cm.

Scomber scombrus Linné This species migrates into the bay and its vicinities in the middle of July. Many were caught with the "spinner", towing behind the boat. Large shoals were observed preying upon young sprats in the latter weeks of July, and 59 individuals were caught with a line and a spinner in 1½ hours near the water's edge on 29.VII.49. It was scanty in the bay in the summer of 1950.

Mugil chelo Cuvier Common in the harbour of Castletown, migrant in Port Erin Bay. Large shoal seen swimming very close to the surface on 22.X.49, and large number caught in the seine-net on 12.XII.49 after dark. The fish ranged from 25 to 34 cm.

Food and Feeding Habits of Inshore Feeding Fishes other than Gadus Virens

In the investigation of the feeding habits of inshore feeding fishes other than G. virens, the number of individuals of some important food species is assessed together as a monthly sample and the results are shown in Table 6.

This investigation reveals the dominance of some categories of food items and as a result the inshore feeding fish may be divided into three groups:

(1) Those predatory entirely on other fish,

(2) Those feeding on a mixed diet of Crustacea Malacostraca, polychaetes and fish,

(3) Those feeding on polychaetes and fish.

Salmo trutta is the only species of the first group and it is found to feed entirely on Ammodytes and is hence an end point of the food chain among the inshore feeding fish.

The second group, the crustacea feeders, includes the Clupea harengus and all the Gadoids in the bay. There is considerable competition among the Gadoids for the crustacean food, as well as for Ammodytes.

The crustacea taken by these fish can be divided into plankton and Crustacea Malacostraca; the latter is subdivided into mysids, isopods and amphipods and decapods.

The plankton in most cases forms a small proportion of the diet of herring, except for the sample obtained on 30.V.50 when the stomachs were gorged with large numbers of Calanus and a number of 6848 has been counted in a single stomach. Marshall, Nicholls and Orr (1939) find on the Clyde that the inshore young herring "feed mainly

TABLE 6 FOOD OF INSHORE-FEEDING FISHES OTHER THAN COAL-FISH (*G. virens*)

▲ Samples collected from Port St. Mary
* Sample collected from Castletown

l.a. large amount

Species	Date	No. of fish	Size range (cm.)	No. of empty stomachs	*Calanus* sp.	Other copepoda	Plankton	Fish eggs	*Eurydice pulchra*	*Idotea* spp.	*Bathyporeia* spp.	Other Haustoriidae	*Pontocrates arenarius*	*P. norvegicus*	*Nototropis swammerdami*	*Gammarus locusta*	Other amphipods	*Schistomysis spiritus*	Other mysids	*Crangon vulgaris* & *Philocheras trispinosus*	Polychaetes fragments	*Ammodytes* sp.	*Clupea sprattus*	Other fishes
	1949																							
Clupea harengus	3,23, Mar.	15	7-23	4				193		1							10	150			22			
	14 Apr.	22	20-24	14		12	5	178			24			1				5						
	9,21, June	11	17-22	4	19	157	68											3				3		
	▲ 13 June	2	22	1							379			54				108						
	18 July	3	20-21	0			3				2						1	44				8	6	
	1950																							
	4 May	10	10-22	0	21268																			
Total		63		23	21287	169	76	371		1	405			55			11	310			22	11	6	
	1949																							
Gadus merlangus	23,28, Mar.	7	11-15	0					3	2	2							20			1	27		
	14 Apr.	3	11-17	0					6	1	4					1		32						
	8,23, June	20	14-20	3	1		2		1	3		13	1	1				38				11		1
	18 July	14	6-24	0							64				3			138	4					
	15 Aug.	32	7-11	13					3									51				2		
	1,7,17, Sep.	101	7-13	13					116		12		1	1	6	4		208		5		44		
	5,7, Oct.	58	8-13	27	4						1				9			61		2		3		
	1950																							
	11,19, May	5	15	0					14		45	2		73		1		65						
	17 Aug.	30	7-23	13														31		3		7		
Total		270		69	5		2		143	6	128	15	2	75	18	6		644	4	10	1	94		
	1949																							
G. pollachius	24,30, Mar.	4	20-24	1						2	1				8	3	27	24						
	24 June	8	23-26	0					2		177		84			3	5	74				11	2	
	29 June	2	22 26	0						8							601		197					
	1,17, Sep.	4	25-28												1	1		62				8		
	1950																							
	19 May	1	15	0														38						
	19 June	9	24-29	0						8						2						25		
Total		28		1					2	18	178		84		9	9	633	198	197			44	2	
	1949																							
G. callarias	23 Mar.	1	18								1											4		
	15 Aug.	2	7- 9										1					2				1		
	1 Sep. 21 Oct.	5	8-30						2	2	1		1				1	10	2			1		
	1950																							
	17 Aug.	30	6-11	14									1		2	1	2	10	21	3		1		
Total		38		14					2	2	2		3		2	1	3	22	23	3		7		
	1949																							
G. minutus	14 Apr.	1	15	0					2									1						
	8,23, June	10	9-15	0			6		6		16	1	1	23				56	2	1		1		
	2,18, July	48	9-16	1			18				4		2	2			1	1036	12	13				
	1950																							
	28 Mar.	1	10	0														8						
	11,19 May	28	10-12	4			1		16		51	11		1		3		28		1				
	1951																							
	13 Feb.	28	8-10	0							10		13			3		415	3		3			
Total		116		5			25		24		81	22	16	26		6	2	1544	17	15	3	1		
	1949																							
Pleuronectes platessa	2,18, July	18	8-19	3																	l.a.	12		
	1 Sep.	17	4-14	14					1											1	l.a.			
Total		35		17					1											1	l.a.	12		
	1949																							
Salmo trutta	14 Apr.	1	33	1																		9		
	8,23, June	6	29-38	0																		9		
	17 Sep.	2	27 29	0																		46		
	1950																							
	26 Jan.	1	36	0																		9		
	28 Apr.	2	36	0																		10		
	1951																							
	21 Jan.	1	31	0																		39		
Total		13		1																		113		

on Calanus and on May 26 there were 1856 Calanus per gut".

Plankton occurs rarely in the diet of poor cod, young whiting and cod. Calanus is the only copepod found on 3 occasions in young whiting; other plankton such as zoea and metazoea stages of decapoda and cypris larvae of cirripedia were found in small numbers in poor cod in May, June and July.

Of the mysids, Schistomysis spiritus is the most important food species for the crustacea feeders. It is found in herring and all members of Gadoids. Large shoals of young whiting, cod and coal fish have been observed feeding close to low water's edge. One seine-netting sample obtained on 17.VIII.50 contained 115 young whiting, measuring 70-235 mm. and 67 young cod, measuring 63-115 mm. and 39 young coal fish measuring 81-139 mm., and examination of 30 stomachs of each species revealed 30, 10 and 899 specimens of Schistomysis spiritus respectively. From Table 6, some idea of the competition over the same food species among the gadoids may be gained, by comparing the food content of different fish caught under the same conditions on the same date. Other mysids, such as Paramysis arenosa, Siriella armata, S. jaltensis and Leptomysis linguura were found only occasionally in the stomachs and were evidently of less importance as food. Of the isopods, Eurydice pulchra was a comparatively important food (11.8%) for young whiting, less important (1.6%) for poor cod, and only occasionally eaten by pollack and young cod. Idoteidae were found in Herring and all gadoids in small numbers, except for one poor cod on 24.III.49 that contained 38 young Idotea emarginata.

Of the amphipods, Bathyporeia pelagica was most frequently eaten by herring and young gadoids (12.6% in young whiting and 5.1% in poor cod, 33.7% in pollack). 356 male specimens were found in a herring stomach collected at Port St. Mary. Pontocrates arenarius and P. norvegicus were of second importance as a food source. Other amphipods, including the common Gammarus locusta and Nototropis swammerdami and 11 less common genera occurred sparingly in the diet of these gadoids.

Crangon vulgaris and *Philocheras trispinosus* were the only Decapods found in young whiting and poor cod, and more in the latter than in the former.

Polychaetes occurred on two occasions in young whitings and in 10 out of 24 poo· cod collected on 13.II.51. It is interesting to note that both Nephthys and Phyllodoce occurred in the diet of herring; the former was found in 7 fishes out of 22 and the latter found once in the same sample of fishes.

The crustacean feeders are also predatory on other fishes. Ammodytes form part of the diet of young whiting (8.5%), cod (8.6%) pollack (3.9%) and herring (1.6%). In the food contents of young whiting, Ammodytes occur in 47 fishes (15.1%) out of 303, and were found only on one occasion in poor cod and on 3 occasions in herring. In spite of its small number as compared with that of crustacea, it is relatively a significant food because of its much larger size, ingested Ammodytes measuring from 32 to 102 mm. in length.

Other fish constitute a small portion of the diet of the gadoids. *Clupea sprattus* occurred on 3 occasions in 3 herrings collected on 18.VII.49. 10 mackerels caught in the same net, except one with an empty stomach, were distended with *Clupea*.

A young whiting, measuring 191 mm., was found to have devoured a young plaice of 37 mm. and a young whiting, measuring 85 mm., was found in a pollack, measuring 280 mm. on 1.X.49.

In the third group, polychaete segments (exclusively the tail piece of Arenicola) were found in small number of young plaice. Ammodytes also occurred in the diet of young plaice. 12 specimens varying from 43 to 112 mm. were found in 5 plaice, 99-195 mm., and 4 Ammodytes (43-86) in a plaice, 161 mm.

Discussion

The inshore fish are essentially migrants. Of the few residents, the plaice occurs in comparatively small numbers and other species of abundance such as *Ammodytes spp.* and *Gobius ruthensparri* become food species for the predatory immigrants.

The immigrants, according to their state of growth and their breeding activity, fall into three distinguishable groups:
(i) the juveniles, (ii) the pre- and post- spawning breeders, (iii) the stragglers.

The juvenile migrants comprised different age groups, varying from the O-group to the second and the third year group individuals. The occurrence of young whiting in summer until autumn, and of the O-group coal fish in the autumn, followed by the second and the third year groups of coal fish in winter, form together a chain of migration almost continuous throughout the year. The inshore migration of the young fish probably represents a transitional period between the planktonic feeding of the post-larval stage and the larger crustacean and fish diet of the older age groups. The inshore water provides an ideal feeding ground in its abundance of crustacea of suitable size and of small fishes.

The visit to the inshore water of the herring after the spawning and of the poor cod prior to and after the spawning is probably connected with feeding activity. Menon (1950) shows that in poor cod an active feeding period follows immediately after the spawning off Plymouth in April and May. The period of inshore migration synchronizes with the active feeding period.

The stragglers are of those species which occur irregularly. It is examplified by the irregular occurrence of large shoals of mackerel in the bay in July of the year 1949, after the appearance of a large shoal of young sprats in the shallow water (Bower, 1950), both being scarce in 1950. Hartley (1939) observes the same correlation in the Tamar and Lynher estuaries and he considers the irregular occurrence of mackerel "has a comparatively small effect on the resident fauna of the estuaries and only appears when some organism suitable for their food is unusually abundant".

The appearance of mullet, on the other hand, seems to bear no relation to the food source, and thus the irregular occurrence in the winter is possibly part of their routine migration.

Hartley (1948) surveys the feeding habits of a community of fresh-water fishes in the River Cam and Shepreth Brook at Barrington, and draws up three generalisations: (1) between no two species is there a true identity of feeding habit, (2) with the exception of fish-eating pike, there is a great degree of general competition between all the fish of the community, and (3) the organisation of this animal community is qualitatively straightforward.

Hartley's generalisations apply satisfactorily to the feeding habit of the group of marine fishes in the bay.

The dietary of the young gadoids is similar to a great extent among the species, and yet each species retains to some extent its own peculiarities, Table 6. The diet of young whiting, cod and pollack, share the same high percentage of crustacea food (90.7, 96.1, and 92.4% respectively) and some amount of fish (8.5, 3.9, and 8.6%). The poor cod differs from the above species in the extremely low percentage of the fish diet and higher numbers of <u>Crangon vulgaris</u> and plankton. The coal fish also feeds on large numbers of crustacea malacostraca, but plankton forms its staple food item in October, November and February. This feeding habit distinguishes this species from other members of Gadidae.

It is shown that there is an intense competition for the fish food among the sea trout and the other species of the Gadidae. The young whiting and young cod take a greater proportion of fish food than the other gadoids. Lebour (1919) has shown the carnivorous instinct of young whiting, in that a 22 mm. larvae devoured 10 mm. larvae of its own species, and fish fragments have been found in larvae of 22 - 75 mm.

The advantage to be gained from fish food as compared with copepod food in the diet of perch has been illustrated by Allen (1935). The advantage of fish content as compared with other crustacea contents in the diet of the young gadoids may be illustrated as follows. Taking 100 individuals of each species as a base, the dry weight of <u>Ammodytes</u> of the size range 58-63 mm. is about 41.5 gm.; of <u>Schistomysis spiritus</u>, a random sample collected on 26.IV.49, is 201 mg.;

and of Pontocrates arenarius is 49 mg.; of Calanus is 18 mg.; and of Sagitta (mainly S. elegans) is 31 mg. A comparison shows an Ammodyte of 60 mm. is equal to about 69 Schistomysis spiritus, 280 Pontocrates arenarius, 760 Calanus, and 430 Sagitta. The fish diet is thus of greater advantage though both its number and frequency of occurrence are considerably lower as compared with that of crustacean organisms.

Hartley (1939) records the fish taken by tuck-net in the Tamar and Lynher estuaries. The members of Gadidae, save for the absence of G. virens, contained in his materials are similar to a great extent to those of Port Erin Bay. In comparing the feeding habit of the gadoids in these two localities, the food contents of Hartley's original table (p. 52) were assessed in seven categories, and the percentage of each category was based on the number of the species recognised, the number of food fragments, e.g. crustacean fragments, Teleost remains, etc., being excluded in the calculation. For those food species that contained less than 100 organisms in total, the actual number of each category was represented. The results from Port Erin Bay were recorded in a similar method. (Table 7).

Comparison of these two tables reveals the common point in the feeding habits that the gadoids are mainly crustacean feeders. On the other hand, the results show the marked contrast at these two localities, regarding the importance of different food species. It is interesting to note that Crangon vulgaris is of importance in Tamar and Lynher estuaries while mysids and amphipods are important in Port Erin Bay. The total number of food organisms that each species has ingested is considerably higher at Port Erin Bay than at the Tamar and Lynher estuaries. The higher number of food organisms at the former locality probably indicates the abundance of certain food sources.

From the ecological standpoint, the food species ingested by the gadoids in the Tamar and Lynher estuaries and Port Erin Bay show more contrast than similarities, except for some species such as Crangon vulgaris, Praunus flexuosus, Gammarus locusta, Apherusa sp., and

Table 7

Comparison of the food of young Gadoids in the Plymouth district and Port Erin Bay

Tamar and Lynher Estuaries 1936 - 1937 (Hartley)

	G. merlangus		G. pollachius		G. callarias		G. minutus		Total
No. of fish containing recognis-able food	355		163		21		25		564
	No.	%	No.	%	No.	%	No.	%	
Pisces	24	6.3	20	11.9	1		1		
Crangon vulgaris & Leander sp.	231	61.4	44	26.1	20		13		
Neomysis vulgaris, Schistomysis ornata and other mysids	81	21.5	60	35.7	1		4		
Isopods & Amphipods	22	5.8	40	23.8	1		9		
Plankton	7	1.8	3	1.7	-		-		
Polychaetes	8	2.1	1	.5	-		1		
Others	3	.8	-	-	-		-		
		100		100					

Port Erin Bay 1949 - 1950

	G. merlangus		G. pollachius		G. callarias		G. minutus		Total
No. of fish containing recognis-able food	211		18		37		101		367
	No.	%	No.	%	No.	%	No.	%	
Pisces	97	8.1	21	3.9	6	8.5	1		
Crangon vulgaris &	10	.8	-	-	3	4.2	15	1.0	
Philocheras trispinosus	64								
Schistomysis spiritus and other mysids	649	54.6	198	37.0	45	64.2	1240	86.4	
Isopods & amphipods	414	34.8	315	58.9	16	22.8	151	10.5	
Plankton	7	.5	-	-	-	-	25	1.7	
Plychaetes	10	.8	-	-	-	-	22	-	
Others	-	-	-	-	-	-	-	-	
		100		100		100		100	

plankton. Neomysis vulgaris and Corophium volutator in the Tamar and Lynher estuaries are evidently inhabitants of muddy ground and brackish water. The same species occur in great abundance in the Silverburn estuaries at Castletown, Isle of Man. Two pollack obtained from the inner harbour of Castletown on 29.VI.49 contained respectively 204 and 273 Gammarus zaddachi, 33 and 92 Corophium volutator, and 113 and 74 Neomysis vulgaris.

The fact that the same species of fish feed on different items at different localities is a matter of common experience. Any species eaten in a particular area will possibly be of "those most numerous and/or easily available", (Steven,1939) within the feeding habit of the fish, whether it is a crustacean, molluscan, fish, or mixed feeder.

The availability of the food organisms depends greatly on their size of both upper and lower limits (Elton, 1927). The potential value of a bed of Lamillibranchs as food for fishes has been considered by Ford (1925): "one species such as Syndosmya alba may never grow beyond a size which a medium dab could easily swallow whole, whereas another, such as Cyprina islandica, although it may be easily devoured in its early life, will soon grow to a size quite beyond the largest of shell eating fish, and thus be relatively useless to fishes." It seems that the bottom feeding fishes are very much restricted to the upper limit of the food organism, while the pelagic feeding fishes seem to be restricted by the lower limit of the food organisms. The ability to feed on minute plankton will depend mainly on the feeding mechanism of the fish, such as the structure of the gill rakers (Table 8) and only those species with long and thickly arranged gill rakers will be able to reach the low limit of feeding. The latter assumption is clearly demonstrated in the group of inshore feeding fishes, in which the herring, the mackerel and the young coal fishes are able to adapt themselves to feed either on plankton, or large crustacea, or fish, in accordance with the abundance of food source. The O-group cod and whiting feed scarcely at all on the plankton, possibly because of the short and less number of gill rakers, and thus tend to hunt for larger food organisms. To consider the change of food with

Table 8. Measurements of Gill Rakers

Date	Species	Body length (Standard length) in cm.	No. of Fish	Total no. of gill rakers	No. of gill raker per 5 mm.	Longest gill raker, in mm.
14.XI.49	*Gadus virens*	38	1	36	4	9
28.II.50	"	24-27	8	33-38	5-6	6.3 - 7.1
12.IV.50	"	16-17	10	33-38	7-8	3.6 - 5.0
17.VIII.50	"	10-13	5	35-37	9-11	2.8 - 3.7
"	"	8-0	5	35-36	11-15	2.2 - 2.5
17.VIII.50	*Gadus collarias*	6.0-9.0	10	19-22	8-12	1.5 - 2.2
"	"	10-11	4	20-21	7-9	2.3 - 2.7
17.IX.49	*Gadus pollachius*	25,26	2	22,26	4,5	6.8, 7.3
5.X.49	*Gadus merlangus*	8-12	9	19-21	6-9	1.8-2.5
5.X.49	*Gadus minutus*	11	3	18	10-11	1.8 - 2.0
5.X.49	*Scomber Scomber*	32	2	46,48	5	17.2-22.0

growth, it seems necessary to consider first of all the change of feeding mechanisms.

Steven (1930) states that "the availability of any animal for food, leaving out consideration of size, will depend on:

1. The habits and activity of the organism itself;
2. The habits and activity of the fish."

The habits and the activity of both Crustacea Malacostraca and the fish have been shown in the previous sections. It seems reasonable to assume that the food organisms show a higher availability when sharing the same habitat and having a similar mode of living as their predators. The young plaice is a bottom feeder and thus its diet is confined to the bottom forms. The sand-eel (*Ammodytes*) and the lugworm (*Arenicola*) in the diet must have been pounced upon as soon as they emerged from the sand. The young gadoids and herring, on the other hand, are pelagic feeders, and the free-swimming forms will be more important to them than the bottom living forms. Comparison of the fauna (Table 9) and the dietaries of the young gadoids in the bay (Tables 4 and 6) reveals that the degree of coincidence is notably high. A more striking feature is the confinement of the feeding of these gadoids to a definite area. This is seen in the coincidence of the facts that Schistomysis spiritus is both a staple food item of the young gadoid and a predominate species in the particular area bordering the intertidal and the shallow waters. During the visiting period of poor cod, young whiting, cod and pollack in the months from July to October, the crustacean faunas are fairly abundant in the shallow water, but none of the species, such as Praunus inermis, Hippolytes varians, Pandalus montagui and Dexamine spinosa, has been recorded in the stomach contents of these gadoids. Steven (1930) states that "animals of a suitable size for food, although living in the same area, may move in quite a different plan from that frequented by the carnivore and so, being inaccessible, remain outside a food chain from which size alone does not preclude them." The feeding of the young gadoids at a certain level might account partly for the "selective" feeding. Most of the crustacea of the shallow water inhabitants either hide in the detritus or among patches of living algae, and thus are less exposed to the predators. The perfect harmony in tone of colour of some of the species (such as Hippolyte varians) with the weed, afford considerable camouflage against their enemies. The distribution of the crustacea over a wide area in the shallow water probably further reduces their accessibility. There is not much reason to assume that the shallow water species are less available than those close to the water's edge, and so the young gadoids 'reject' the former and 'select' the latter. In such a case, accessibility is presumably a more important factor than availability. This can be substaniated by Allen's (1941) results on the feeding of the young salmon in a rapidly flowing stream where potential food items may habitually live under the shelter of stones and so are made relatively inaccessible.

Light seems to have a more direct effect on the food organisms than on the fish regarding the feeding habit of different fishes. As has been shown in the experiments, the coal fish is able to continue with its feeding in darkness whenever food organisms are available. The small amount of Schistomysis spiritus found in coal fish stomachs can be explained as a result of the inter-action of the movement of the food organisms and the fish. It is supposed that the fish move inshore with the approach of darkness or after dark. When the fish move inshore with the approach of darkness, the accessibility of food organisms would depend mainly on the states of tide. The second and the third year groups coal fish can hardly approach the water's edge in the ebbing tide, though Schistomysis spiritus swarms there at dusk. In the approach to the shore after dark Schistomysis spiritus performs vertical movement and disperses near the surface in a wide area. Both the diurnal vertical movement and the dispersion will reduce the accessibility of the species. The shallowness of the water's edge has less effect on the feeding of the O-group gadoids. The number of organisms will be reduced in the diet when there is a competition among large shoals of fish, such as coal fish and young whiting.

Summary

1. In Port Erin Bay, monthly bottom and surface samples of Crustacea Malacostraca were taken by D-net and surface tow-net in 4 lines of transect stations, at 4 tidal periods, both in the daytime and at night, during a period from July, 1949, to August, 1950. Samples were also taken from the water's edge by wading.

2. Faunas include Mysidacea, Decapoda Natantia, Isopoda and Amphipoda of Crustacea Malacostraca.

3. The seasonal abundance of some consistent species is shown. Relationship between seasonal abundance on one hand and habitat and breeding on the other of different species is discussed.

4. The breeding period of most species is recorded. Relationship between season and size of the ovigerous females and fecundity of some species of Mysids and sublittoral amphipods and isopods is shown.

5. The diurnal movement of most species of the fauna is discussed, as well as its controlling factors.

6. The inshore migration of *Clupea harengus*, *Gadus minutus*, and young *Gadus virens*, *G. merlangus*, *G. callarius*, *G. pollachius*, is recorded from 2-4 seine-netting samples every month from October, 1948, to January, 1950. Samples were obtained less frequently from February to December, 1950.

7. The growth rate, the condition factor, the length and weight relations of the 0 to 3 year groups of *Gadus virens* are shown.

8. The stomach contents of all gadoids and of some of the other species are given, both quantitatively and qualitatively. The feeding activity of *G. virens* is expressed by plotting the average weight of the stomach contents against the months of the year as a graph.

9. The correspondence between food contents and the faunas is noted, and the availability and accessibility of different food species and the competition over the same food species among different fish are discussed.

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Appendix 1 Surface and bottom temperature (°C) of different localities in Port Erin Bay.

Date		Locality		
1950		Raglan Pier	Life-boat Slip	Breakwater
May 16	Surface	10.9	10.1	9.8
	Bottom	10.8	9.2	9.1
June 13	Surface	13.4	12.4	12.1
	Bottom	13.1	11.6	11.4
July 31	Surface	14.9	14.9	14.5
	Bottom	14.8	14.4	14.3
Aug.21	Surface	14.9	15.0	14.5
	Bottom	14.7	14.4	14.4
Oct.20	Surface	12.9	12.8	12.8
	Bottom	12.9	12.8	12.8
Dec.28	Surface	6.9	6.9	6.9
	Bottom	6.9	6.9	6.9
1951				
Jan.31	Surface	7.5	8.0	8.1
	Bottom	7.6	7.6	7.6
Feb.29	Surface	7.2	7.3	7.2
	Bottom	7.2	7.4	7.2
Mar.30	Surface	7.2	7.0	6.8
	Bottom	7.4	6.9	6.8

APPENDIX

Size distribution (length frequency) of some Crustacea Malacostraca at Port Erin Bay, during the period from September 1949 to August 1950.

Crangon vulgaris

Size range (mm.)

Date		70	65-69	60-64	55-59	50-54	45-49	40-44	35-39	30-34	25-29	20-24	15-19	10-14	6-9	5	Weight (gm.)
1949																	
25-26 Sept.		2	2	4	9	11	22	67	44	24	24	17	5				
30 Oct.		2	5	8	15	28	42	40	36	7	3	1					120
24-25 Nov.	1	1	8	14	21	36	44	17	12	1							158
30 Dec.			3	1	3	6	1										15.1
1950																	
24 Jan.	7	2	2	7	10	8	5	2	2								31.4
21.Mar.	7			1	1	3	2										24.4
4 May	2			1	2	1								2	76		11.2
31 May	3												8	37	42	9	9.9
7 July	2				4					17	57	28	60	77	16	3	26.5
21 July	1	10			3				36	91	66	84	105	9	1		89.9
28 July		6			2		2	27	132	123	79	122	87	4	7	1	137
21 Aug.		2	2			1	27	63	50	50	110	46	6	6	2		98

Philocheras trispinosus

Size range (mm.)

Date		31-34	26-30	20-25	15-19	10-14	5-9	Weight (gm)
1949								
25-26 Sept.				14	48	162	73	
30 Oct.		1	5	37	95	266	36	16.9
24-25 Nov.			11	46	82	54		12.4
30 Dec.				2				.2
1950								
24 Jan.	3	5	17	23				4.6
21 Mar.	21	1	19	49				8.7
4 May	18		9	28				5.8
31 May	3		5	7				2.1
7 July	1	1	2		1	12		.8
28 July	5	2		1	4	50	5	3.2
21 Aug.	5	1			5	16	4	2.8

Hippolyte varians

Date	Ovigerous females	26-29	20-25	17-19	13-16	11-12	6-10	5	Weight (gm.)
		Size range (mm.)							
1949									
25-26 Sept.	36		193	399	1286	723	1955		
30 Oct.		4	301	415	1320	701	1021		86.9
24-25 Nov.		6	50	68	242	136	83		19.2
30 Dec.			6	2	2				.5
1950									
24 Jan.			8	4	16	2	2		1.8
21 Mar.	16		6	2	19	2			2.5
4 May	12	2	2	13	35	1			2.8
31 May	2		4	7	6				.7
7 July	10			18	34	47	127		3.9
28 July	23		1	46	100	95	171	6	7.4
21 Aug.	58	1	7	28	199	148	294		12.4

Spirontocaris cranchi

Date	Ovigerous females	23-26	19-22	14-18	10-13	6-9	Weight (gm.)
		Size range (mm.)					
1949							
25-26 Sept.	1			35	189	361	
30 Oct.			7	43	141	67	3.4
24-25 Nov.		2	1	14	45	17	1.8
30 Dec.					3		.2
1950							
24 Jan.				3	6		.4
21 Mar.				15	17	2	.8
4 May.	7			26	33	1	2.1
31 May	7			7	4		.7
7 July	5			16	8	1	1.1
28 July	3		1	11	7	1	.7
21 Aug.	3			6	15	17	.9

Pandalus montagui

Date	55	50-54	45-49	40-44	35-39	30-34	25-29	20-24	15-19	10-14	Weight (gm.)
1949											
25-26 Sept.		2	14	11	7	3	1				
30 Oct.	2	12	15	2							29.1
24-25 Nov.		2									2.6
30 Dec.				None							
1950											
Jan.-April				None							
31 May									3	28	.2
7 July							8	53	13		4.8
21 July						16	48	19			11.1
28 July					15	77	54	16			27.6
21 Aug.			2	16	56	32	7				37.9

Processa Canaliculata

Date		40-44	35-39	30-34	25-29	20-24	15-19	10-14	5-9	Weight (gm.)
1949										
25-26 Sept.		3	2	3	18	22	31	40	5	
30 Oct.		1	5	8	17	34	76	72		
24-25 Nov.			1	1	2	5	17	4		3.0
30 Dec.				2		1				0.9
1950										
24 Jan.						1	1			.2
21 Mar.	1	1				1				2.1
4 May					3	2				.8
31 May						1				.09
7 July				1	3					1.0
28 July	1				1					.9
21 Aug.			1							.6

Praunus flexuosus

Date		Size range (mm.) 25	22-24	20-21	16-19	13-15	9-12	6-8	Weight (gm.)
1949									
25-26 Sept.	26	0	7	28	376	371	410	76	
30 Oct.	2	4	27	85	353	161	30		17.4
24-25 Nov.		17	19	33	92	56	7		7.5
30 Dec.		4	1	2	4	2			.6
1950									
24 Jan.	1	4	3		11	2	3		.9
21 Mar.	2		5	3	8				
4 May	14			2	9		9		1.6
31 May	4				2	5	4	2	.4
7 July	9			4	20	61	70	16	2.4
28 July	39			2	46	70	66	27	4.4
21 Aug.	40			2	38	63	31	17	4.3

Praunus inermis

Date		Size range (mm.) 17	13-16	10-12	6-9	5	Weight (gm.)
1949							
25-26 Sept.	182			548	698	15	
30 Oct.	47			829	55		8.1
24-25 Nov.	6			158	25		1.8
30 Dec.	1			4			.04
1950							
24 Jan.	2		8	21			0.4
21 Mar.	50		21	36	1	1	2.2
4 May	58		38	19	173	25	3.1
31 May	29.		58	236	133	14	3.0
7 July	493	4	131	403	111	6	13.3
28 July	645	5	64	636	1123	296	23.3
21 Aug.	405		82	379	202	60	11.5

Siriella armata

Date		Size range (mm.) 22-25	19-21	17-18	13-16	9-12	7-8	Weight (gm.)
1949								
25-26 Sept.	26	4	19	58	229	1926	65	
30 Oct.	4		102	51	144	91	12	7.3
24-25 Nov.	15	133	99	112	156	111	26	13.8
30 Dec.		7	3	1	1	1		.5
1950								
24 Jan.	1	27	14	8	7	1		1.8
21 Mar.	1	2	4					.2
4 May	1	1	1				1	.09
31 May	2	3						.3
7 July	1	1			5	8	1	.2
28 July	3		1	13	6	15	3	.5
21 Aug.	21	2	33	7	6	5	5	2.0

Siriella jaltensis

Date	Size range (mm.)	13-16	12-13	10-11	7-9	5-6	Weight (gm.)
1949							
25-26 Sept.	37	18	1	8	102	639	
30 Oct.	10	11	29	58	79	4	
24-25 Nov.	1	24	28	98	170	46	2.4
30 Dec.		6		139	294	96	1.8
1950							
24 Jan.		4	2	1			
21 Mar.		2	2				
4 May		1					
31 May		2			1	1	
7 July	18	41	5	43	30		1.3
28 July	22	9	9	11	4		
21 Aug.	1		3	11	2		.12

Leptomysis linguura

Date	Size range (mm.)	10-11	7-9	5-6	4	Weight (gm.)
1949						
25-26 Sept.	26	27	26	12	2	
30 Oct.	10	9	5	4	12	
24-25 Nov.	24	70	152	833	4	3.6
30 Dec.						
1950						
24 Jan.	12	7	1	2		
21 Mar.			1	1		
4 May	1	1				
31 May	1	1	1			
7 July	28	20	3			
28 July	29	17	4			
21 Aug.	23	27	6			

Schistomysis spiritus

Date	Size range (mm.)	14	10-13	7-9	3-6	Weight (gm.)
1949						
25-26 Sept.	280		796	106	10378	
30 Oct.	536	7	2558	3592	24513	31.5
24-25 Nov.	255		8673	9069	15927	103.0
30 Dec.			1223	258		11.5
1950						
24 Jan.	565		14443	2713	1243	122
21 Mar.	1024		577	16	2	18.8
4 May	1185	500	813	211	9573	36
31 May	531	50	901	818	1302	17
7 July	98	7	609	1331	15482	16
21 July	30819	3995	15054	19270	44652	514
28 July	1047	215	1976	14339	96603	126
21 Aug.	114	1	380	1789	121731	57

Paramysis arenosa

Date	Size range (mm.)						Weight (gm.)
		10	8-9	6-7	4-5	3	
1949							
25-26 Sept.	109		64	12	62		
30 Oct.	26		21	44	98	20	0.6
24-25 Nov.	16		46	104	19		0.8
30 Dec.	1		2	1			
1950							
24 Jan.	21	71	15				0.4
21 Mar.	16	15	11				
4 May	54	21	37	77	6		1.1
31 May	109	1	28	19	27		1.0
7 July	185	8	96	86	353		2.1
28 July	1112	7	328	950	666		6.7
21 Aug.	189	1	168	365	225		1.8

Gammarus locusta

Date	Size range (mm.)						Weight
1949		20-24	15-19	10-14	6-9	3-5	
25-26 Sept	47	13	10	45	130	100	
30 Oct.	31	5	34	63	78	29	6.0
24-25 Nov.	99	16	84	180	266	65	15.6
9 Dec.	82	5	57	185	217	60	12.0
16 Dec.	36	1	19	84	198	822	8.0
30 Dec.			1		2		
1950							
24 Jan.	1		5	9	10	28	0.5
21 Mar.	5	4	4	4	23	1130	1.7
4 May	36	5	12	93	99	31	4.5
31 May	4	1	14	16	10	4	1.0
7 July	30	11	32	92	113	145	5.8
28 July	185	48	120	172	69	20	19.7
21 Aug.	5	3	10	32	54	127	2.1

Dexamine spinosa

Date	Size range (mm.)							Weight
1949		13-15	11-12	9-10	6-8	4-5	3	
25-26 Sept.	10		21	26	288	315		
30 Oct.			11	40	352	76		4.6
24-25 Nov.				15	37	3		0.6
30 Dec.								
1950								
24 Jan.				3	2			
21 Mar.	2		1	7				
4 May				4				
31 May	1	2	5	2	2	5		0.3
7, 21 July	70	16	27	66	49	44		5.3
28 July	30	14	9	31	54	53	1	2.8
21.Aug.	14	1	6	23	58	79	36	1.9

Idotea baltica

Date		Size range (mm.) 25-29	20-24	15-19	10-14	6-9	3-5	Weight (gm.)
1949								
25-26 Sept.	5	2	6	5	14	14	18	
30 Oct.	24	7	13	17	38	9		9.0
24-25 Nov.	12	6	17	56	262	529	672	27.4
9 Dec.	6	2	2	22	77	170	131	7.3
16 Dec.	1		5	7	148	1318	2962	24.3
30 Dec.						3		
1950								
24 Jan.	1				3	4		0.3
21 Mar.	1		1	3	3	19	205	1.2
4 May				4	7	18	36	1.4
31 May	1			4	5	32	15	1.5
7 July	7		8	15	18	14		2.5
28 July	27		24	32	35	34	43	26.5
21 Aug.	1	1	4	1	12	94	155	3.2

Idotea emarginata

Date		Size range (mm.) 30-33	25-29	20-24	15-19	10-14	6-9	3-5	Weight
1949									
25-26 Sept.	4			1	4	2	6	6	
30 Oct.	11			6	3	5	5		2.0
24-25 Nov.	60			27	34	189	508	549	20.7
9 Dec.	11			6	16	85	205	147	9.3
16 Dec.	15			2	16	91	599	1272	15.2
30 Dec.				- None -					
1950									
24 Jan.					1	1			
21 Mar.							1	8	.3
4 May	67			7	7	46	112	120	19.3
31 May	8	5		4	22	7	27	68	4.4
7 July	132			11	42	400	1106	7402	41.0
28 July	78			12	91	219	861	529	26.5
21 Aug.	5			2	7	30	62	2	3.2

Appendix *Schistomysis spiritus*. Number of individuals obtained per haul at different states of tide at different periods of the day. The interval between successive hauls was approximately 10 min., each haul lasting from 10 to 15 min. The catches were sorted into ♀e, ovigerous females and 7-15 and 3-6 mm. size groups.

Date	Time of start of sampling (hrs.)	State of tide (approx.)	1 bw ♀e	1 bw 7-15	1 bw 3-6	1 bT ♀e	1 bT 7-15	1 bT 3-6	2 bw ♀e	2 bw 7-15	2 bw 3-6	2 bT ♀e	2 bT 7-15	2 bT 3-6	3 b all	4 b all
			size range (mm.)													
			Number per haul													
1949																
9-10 June	1810	M.T.L.		—			—		9	8	2520	16	19	980		
	0220	H.W.	320	300	1400			5		—		46	440	2140		
	0510	L.W.		—			—		40	370	3180	9	10	419		
	1030	H.W.		no sample			none			—		16	400	2580		
25-26 July	0530	L.W.		—			—		4653	10293	18612	2	7	13		
	1106	H.W.	60	60	2380					—		0	0	5		
	1945	L.W.		—			—		200	1300	1160	0	0	1		
	2325	H.W.	16	21	2920		no sample			—		3	57	7		
25-26 Sept.	0130	H.W.	35	250	3850	4	6	122		—		4	30	7		
	0835	M.T.L.		—			—		8702	8972	23364	96	115	432		
	1345	H.W.	115	345	4600	18	103	1244		—		4	28	11		
	2005	L.W.		—			—			1	69	4	4	54		
29-30 Oct.	1515	L.W.		—			—			719	20190	258	1720	399		27
	2050	H.W.	21	43	35	33	46	2		—		2	11	5		
	0230	L.W.		—			—		26	15	18	0	3	0		
	0830	H.W.	23	532	409	161	2901	3194		—		11	163	248		
24-25 Nov.	1400	H.W.		none		37	1694	2979		—		4	1003	474		1
	2100	L.W.		—			—		42	126		0	13	0	2	
	0200	H.W.		none		0	5	32		—		0	16	12		
	0903	L.W.		—			—		172	14112	11568	0	770	860		
30 Dec.	1430	L.W.		—			—			none		0	391	0		
	1939	H.W.	0	1040	0		no sample			—		0	46	0		
1950																
17 Jan.	1700	L.W.		—			—		336	22557	880	2	10	1		
21 Jan.	0730	L.W.		—			—		338	19248	1296	6	30	16		
24 Jan.	0927	L.W.		—			—		4	126	184	28	697			
	1630	H.W.	96	3296	352	6	143	18		—		14	997	26		
31 Jan.	1810	L.W.		—			—		353	6912	0	42	2028	0		
21 Mar.	1950	L.W.		—			—		794	263	8	0	3	0		
	2305	H.W.		2		189	220	0		—		7	42	0		
29 Mar.	0815	H.W.		none				4	0	0		19	41	0		
4 May	0620	L.W.		—			—		699	2529	7359	23	131	0		
	1320	H.W.	1	0	0				0	0	2	65	324	51		
	1830	L.W.		—			—		342	209	2080	14	87	50		
	0120	H.W.	3	25	3	32	101	28		—		4	18	0		
30-31 May	0910	H.W.	0	0	5	2	245	88		—		7	245	88		
	1630	L.W.		—			—		18	92	98	0	0	66		
	0150	H.W.	499	1288	166	2	65	20		—		2	4	0		
	0610	L.W.		—			—		1	47	810		28	47		
7 July	0410	H.W.	1	246	6760	21	1000	40		—			none			
	1125	L.W.		—			—		1		1240	62	397	110		
	1905	H.W.		110	6020	12	120	1300				1	74	12		
21 July	2130	L.W.		—			—		30811	38318	44653	8	1	0		
28-29 July	1650	L.W.		—			—		84	780	45184	16	63	59		
	2320	H.W.	554	762	1098	28	45	1		—		0	1	0		
	0440	L.W.		—			—		330	13860	48820	0	4	1		
	1030	H.W.	0	14	0	2	141	800		—		33	860	640		
20-21 Aug.	1630	H.W.	6	331	13429	7	250	300		—		6	180	2	16	
	2200	L.W.		—			—		72	2	43	3	0	21	0	13
	0625	H.W.	7	560	23760	6	386	1332		—		0	7	0		
	1110	L.W.		—			—		5	330	82830	1	110	0		

1_{bw} - wading along high water's edge ; 1_{bt} - dredging along mid-tide level; 2_{bw} - wading along low water's edge ; 2_{bt} - dredging close to low water's level ; 3_b - dredging from life-boat slip to White Rock ; 4_b - dredging inside the breakwater ; —— no sample available

Table 9. Number and weight per month of some species of Crustacea Malacostraca in Port Erin Bay.

1949

	9 June no.	29 July no.	23 Sep. no.	30 Oct. no.	30 Oct. wt(gm)	25 Nov. no.	25 Nov. wt(gm)	9-30 Dec. no.	9-30 Dec. wt(gm)
Eurydice pulchra	3	974	87			3			
Idotea emarginata	73	650	21	30	2.0	1367	20.7	2465	24.6
Idotea baltica	42	35	49	108	9.0	1554	27.4	4525	31.6
Bathyporeia spp.	19	36		7					
Pontocrates arenarius	188	16		88		495		57	
P. norvegicus	152	1		163				2	
Nototropis swammerdami	381	359	3173	14		43	.6	1134	9.6
Gammarus locusta	52	59	480	240	6	710	15.6	1738	19.8
Dexamine spinosa	27	238	746	479	4.6	55	.6		
Apherus bispinosa	952	333	2921	182		7		7	
Siriella armata	9	39	2326	404	7.3	652	13.8	13	.5
S. jaltensis	2	191	1035	64	.9	367	2.4	504	1.8
Leptomysis linguura	36		25	40	.18	1083	3.6	50	
Praunus flexuosus	44	203	1380	659	17.4	222	7.5	11	.6
P. inermis	1049	1741	1511	931	8.1	189	1.8	5	.04
Schistomysis spiritus	15997	41791	12161	30153	31.5	33924	103	1481	11.5
Paramysis arenosa	598	593	248	209	.6	185	.8	4	
Crangon vulgaris	124	268	231	182	120	124	158	13	15.1
Philocheras trispinosus	31	261	297	440	15	193	12.4	1	.9
Hippolyte varians	64	966	4607	3762	85	585	19.1	5	.3
Spirontocaris cranchi	32	63	566	258	3.4	79	1.8	3	.2
Pandalus montagui	34	41	59	31	29.1	2	2.6		
Processa canaliculata	3	4	121	213	21.7	30	3.0	3	.7
Leander serratus				2	2.3	2	1.2		
Other Philocherus			11	31	2.9	20	1.9		
Total number	19912	48862	32075	38690		41891		1[illegible]69	
Total weight (gm.)					367		397		117

1950

	24 Jan. no.	24 Jan. wt(gm)	21 Mar. no.	21 Mar. wt(gm)	4 May no.	4 May wt(gm)	31 May no.	31 May wt(gm)	7,21 July no.	7,21 July wt(gm)	28 July no.	28 July wt(gm)	21 Aug. no.	21 Aug. wt.
Eurydice pulchra					387	1.5	24		15		49			
Idotea emarginata	2		26	.3	359	19.3	141	4.4	9093	41.0	1790	26.5	108	3.2
Idotea baltica	10	.3	475	1.2	65	1.4	58	1.5	62	2.5	195	10	268	2.9
Bathyporeia spp.			65		74		27						19	
Pontocrates arenarius	67		82		59		214		790		11		370	
P. norvegicus	43	.3	4		18		120						23	
Nototropis swammerdami	10	.2	1358	1.2	43	.7	11	.2	878	5.1	720	2.5	1397	2.2
Gammarus locusta	30	.5	343	1.7	276	4.5	49	1.0	424	5.8	616	19.7	231	2.1
Dexamine spinosa	47		10		4	.03	17	.3	272	5.3	195	2.8	217	1.9
Apherus bispinosa	6		46		16		11				44		47	
Siriella armata	61	1.8	7	.2	4	.09	5	.2	16	.16	41	.5	79	2.0
S. jaltensis	7	.06	4	.04	1		4	.04	146	1.3	55	.2	17	.12
Leptomysis linguura	20		1		2		3		51		45		56	
Praunus flexuosus	21	.9	18	.93	34	1.6	17	.3	180	2.4	254	4.4	194	4.3
P. inermis	31	.2	109	2.2	313	3.1	470	3.0	1162	13.3	2769	23.3	1128	11.5
Schistomysis spiritus	19064	122	1619	18.8	14182	36	3602	17	17520	16	114180	126	124015	57.0
Paramysis arenosa	117	.4	32		195	1.1	184	1.0	728	2.1	3063	6.7	948	1.8
Crangon vulgaris	44	31.4	15	24.4	84	11.2	99	9.9	669	118	592	137	371	98
Philocheras trispinosus	49	5.5	90	8.5	55	5.3	15	2.4	17	.7	68	3.1	31	1.8
Hippolyte varians	37	1.8	45	2.5	63	2.8	19	.7	242	3.9	442	7.4	735	12.4
Spirontocaris cranchi	9	.4	34	.8	67	2.1	18	.7	30	1.1	23	.7	41	.9
Pandalus montagui							31	.2	157	16	162	27.6	113	37.9
Processa canaliculata	2	.2	3	2.1	5	.8	1	.9	4	1.0	2	.9	1	.7
Leander serratus	4	2.2	8	7.8	23	20.1	1	1.6	4	4.7	4	4.9	3	4.0
Other Philocherus	5	.4	5	.4	3	.3	2	.2	2	.2	2	.2	3	.3
Total number	19682		4351		16332		5143		146260		125322		130415	
Total weight (gm.)		168		72		112		45		240		404		245